GROWTH

A JOURNAL FOR STUDIES OF DEVELOPMENT AND INCREASE

VOLUME XXIII
PAPERS 555-577

1959

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A JOURNAL FOR STUDIES OF DEVELOPMENT AND INCREASE

VOLUME XXIII, NUMBER 1
PAPERS 555-560

MARCH, 1959 $6.00 A YEAR

Second-Class postage paid at Worcester, Mass.

GROWTH

A journal for the coordination of studies of increase and development as general properties of nature. Published by contributors and subscribers on a cooperative, non-profit, non-salary basis. The field of investigation is primary and work will be published in which the approach is through mathematics, physics, chemistry, genetics, embryology, philosophy, and anthropology; just as will studies of development in its several expressions, and of mass increase and the part played therein by nutrition, vitamins, and hormones.

It is published four times a year during March, June, September and December at $6.00 per volume (outside U. S. and Canada, $6.50). Single numbers $2.00. There will be one volume each year.

All manuscripts and subscriptions should be sent to: The Editors of Growth, The Institute for Cancer Research, Fox Chase, Philadelphia 11, Pa.

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Growth, 1959, **23**, 1-11.

BODY DISPROPORTIONS AND PERSONALITY RATINGS IN A GROUP OF ADOLESCENT MALES*

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(Received October 14, 1958.)

SIGNIFICANT relationships between body disproportions and dominant personality traits have been reported previously (1); these disproportions refer to restricted ranges of body ratios or indices diverging strongly from the mean, usually in a unilateral direction. Examples of such disproportions are those which are evidenced by ratios in which the chest is very narrow for the shoulder width, head large for chest size, face very broad for chest width, stature tall for body weight, etc. The importance of these unilateral disharmonic bodily proportions lie in their apparent association with those dominant personality traits which indicate lesser stability and integration, greater sensitivity and complexity of the personality, and lesser capacity for making easy social adjustments, and with those motivations which are less practicable and which lead to more ideational (cerebrotonic) fields of endeavor. That these associations exist is suggested by the data investigated by The Grant Study of Harvard University. Further support for these generalizations was obtained by analyses of a large series of unselected undergraduates rated on the basis of general "soundness" of personality, and a group of students who were referred to the University's student health service for evaluation. It was found that body disproportions were more frequent both in the "less sound" undergraduates and also in those referred for psychiatric care.

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Studies upon which some of the material is based were supported by the Grant Foundation, Incorporated.

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A subsequent study of body disproportions, this time at the adolescent level, was made in connection with an analysis of the morphological characteristics of delinquents and non-delinquents (2). Despite the complicating factor of the age ranges of the two juvenile groups, the results of this investigation showed clearly that in seven out of the ten indices the frequency of disproportions was substantially lower in the delinquent group than in the non-delinquent group. However, owing to certain rigid procedures involved in this delinquency research, no personality trait data characterizing the juveniles were available to the author for correlative analysis (3). Accordingly, it was postulated that since the non-delinquent juveniles were more disproportionate in their physiques, they should be characterized by a relatively greater frequency of those traits indicative of sensitivity and complexity of the personality, and a lesser capacity for making easy social adjustments (4). The delinquents, on the other hand, showing fewer disproportions than the non-delinquents were postulated to have a relatively greater frequency of those traits indicating vitality, directness, relative insensibility to fine external influences, practical organizing and sociability. These postulates were later confirmed in many respects by Glueck and Glueck in their correlative study of physique and delinquency (5).

These studies of disproportions and delinquency in juveniles indicated the need for a further investigation of the relationship of disproportions and personality in "normal" adolescents: the present paper presents pertinent material based on an investigation of a series of adolescents studied at the preparatory school level.

The Material

In the fall of 1938 a research program was inaugurated for the purpose of studying adolescent boys (6). This study embraced such areas as medicine, physiology, psychology, anthropology and sociology in an effort to explore broad aspects of those problems which confront adolescents by investigating a number of fields suspected of influencing individual behavior during this growth period.

As part of this study an extensive series of anthropometric measurements and observations were made by one of the authors (CCS) on 358 ninth grade students. Although this series of students showed a remarkably wide geographical distribution, for the most part their states of residence were confined to the northeastern sector of the

country. Massachusetts contributed 39.1 per cent of the total series, New York State was next with 21.8 per cent, followed by Connecticut with 12.0 per cent representation. A total of 55 per cent of the students came from New England homes.

On the whole, these students were representative of most favorable socio-economic backgrounds. About 20 per cent of the total series reported yearly family incomes of over $20,000. (These figures must be assessed in the light of the 1938 economic picture in the U. S.) The $3,000 to $20,000 category embraced about 63 per cent of the group, with most of the individuals having family incomes approaching the larger rather than the smaller figure. Almost all the students were native born of native parentage.

The group studied was composed essentially of 13, 14, and 15 year old boys, all at the 9th grade level. Those 13 years old comprised 16.2 per cent of the total series, those 14 years old 51.6 per cent, and those 15 years old 29.2 per cent. The average age of the combined series was 14 years and 7.42 months.

Personality Ratings

The personality ratings used in this study were made by one of the authors (JRG). These ratings were assigned on the basis of personal interviews and were intended to indicate the "soundness" of the individual's character structure (7).

The physician who made these ratings had of necessity to orient his point of view to that appropriate to a study of *normal* personality and away from that which would obtain were one engaged in an investigation of persons suffering from mental illness. However, the devices and concepts which a psychiatrist uses were utilized: the differences from a psychiatric interview lay in that the bases for evaluation were the achievements, interests, activities, hopes and attitudes of basically healthy people; these interviews did *not* center around symptoms characteristic of mental illness. Therefore, these interviews reviewed such everyday matters as relationship with parents, teachers and fellow students; interests in the fields of art, music, athletics, mechanics and nature; hobbies, academic interests and plans; fears and moods; sociability; acceptance of, and by, others; jobs and summer activities.

This type of material yielded an impression of what this boy *was like,* and what he could *do,* rather than information which might indicate how he had become the sort of person he was. It allowed an

estimate of whether or not the boy was handicapped by inimicable attitudes, inner tensions or conflicts, but did not attempt to explore them: the main concern was to determine the likelihood of the boy's being able to carry on efficiently in this particular environment. Consequently, psychiatric terminology was avoided in the descriptions of these young people and instead, whenever possible, terms were used which seemed better suited to efforts to describe the individuals who were essentially normal.

On the basis of those interviews each boy was given an overall classification as belonging to one of three groups. Group A contained those who exhibited a stable personality and appeared to be on a "firm foundation" such as Webster implies in his definition of "sound." The 85 boys in Group A represent those individuals who gave little or no evidence that they would have difficulty in handling even the more demanding or unusual problems (social, academic and personal) which occasionally arise in this boarding school situation and at this time of life. Group B (247 individuals) consisted of those who appeared well-adjusted, but who seemed to be somewhat less likely to be able *completely* to realize their potentialities when faced with the usual stresses of school life and of this developmental period. However, the possibility of their succumbing to less than very unusual stress was considered slight. Their flaws were such minor ones as excessive sensitivity, restlessness, inability readily to express feeling (warmth, etc.). Those boys whose personalities seemed weak or inflexible were placed in group C (26 individuals). These individuals exhibited such characteristics as insecurity, instability, and lack of ability to adjust to moderate stress: they lacked competitiveness, or were emotionally unstable, or purposeless, or moody, or were excessively inhibited or asocial.

From the psychological point of view, the A boys would be expected to furnish the most stable and dependable members of this community, and those who would probably be most successful and happy in that particular environment. It was expected that the Group B boys would do well in most circumstances, but that even with support the Group C boys would have little social success and might later present emotional difficulties and related academic problems.

These ratings admittedly were subjective and their validity dependent on the interviewer's experience, intuitiveness and skill. Subsequent developments and the appraisal of others bore out the majority of these judgments and there were few if any instances in which those

rated A adjusted poorly or those who were rated C adjusted well. Of those who were rated A, 89.6 per cent completed the four year course satisfactorily or withdrew for reasons beyond their control; this was true of only 46.1 per cent of the C group.

The Disproportions

In deriving the disproportions to be used in this series of adolescent students, consideration was given to the disproportions and the method of their derivation utilized in the investigation of the group of young adults of the Grant Study.[1] In the case of those young adults, the disproportions and their ranges were empirically derived. There was no fixed mathematical method of formulating them, although in a number of instances the critical levels at which each disproportion was established approximated one sigma distance from the mean of the body ratio under consideration; for the most part their derivation was the considered result of intensive study of the material.

For the purposes of consistency, it was decided to use the same body ratios in the study of these young adolescents as had been previously developed for the members of the Grant Study. However, because of the range of the disproportions a complete carry-over was impossible. This was due to the fact that in the case of the young adolescents we were dealing with a series whose bodily measurements and proportions were still in a state of flux and had not as yet reached a state of maturity and relative stability. Accordingly, new ranges were established for this series based on a fairly rigid formulation. These ranges of the disproportions were computed by marking the critical level or cut-off point for each bodily ratio as close as possible to one sigma distance from the mean of the index. In this way it was possible to take into account the differential growth phase of the adolescent boys and yet derive disproportions which are consistent with those used in the Grant Study material.

Since at the adolescent level the disproportions vary with chronological age, it was necessary to examine the personality groups for age differentials. The mean age for this total series was 14 years and 7.42 months. For the A personality group the mean age was 14 years and 9.64 months, and for the group C the mean age was 14 years and 7.36 months. Group C apparently does not differ from the total series in age, while Group A was on the average only slightly older than the group as a whole: it would appear that the comparisons of the per-

sonality groupings can be made without undue concern for the effect of age on the disproportions.

Table I lists the disproportions and their ranges as computed for this series. For the purpose of comparison the ranges of the Grant Study disproportions are also given.

TABLE I
DISPROPORTIONS FOR SERIES OF ADOLESCENT BOYS

	Adolescent Boys	Grant Study
Height/$\sqrt[3]{\text{weight}}$ index	13.9-x	13.5-x
Biacromial diam. x 100/chest circ. index	47-x	48-x
Chest breadth x 100/biacromial diam. index	x-67	x-70
Chest depth x 100/biacromial diameter index	x-46	x-47
Hip breadth x 100/biacromial diam. index	76-x	75-x
Head circ. x 100/chest circ. index	72-x	64-x
Chest circ. x 100/stature index	x-45	x-48
Calf circ. x 100/biacromial diam. index	x-85	x-85
Face breadth x 100/chest breadth index	55-x	50-x
Hand size (hand length x hand breadth) x 100/weight index	128-x	110-x

ANALYSIS

In this section the various personality ratings are analyzed for frequency of the disproportions. In Table II the percental occurrence of each disproportion is contrasted with the frequency in the series as a whole.

What is interesting to note in this table is the consistent pattern of differentiation of the personality groupings from the percental frequency of the total series. Thus, for example, in the case of the height /$\sqrt[3]{\text{weight}}$ disproportion we find the A "soundness" group to have the smallest percentage of individuals with extremely linear body builds, the B group with a somewhat larger percentage, while the C "soundness" group displays the largest percentage of persons with extremely linear physiques. Similarly, in regard to the chest breadth/biacromial diameter disproportion, the A group shows the smallest percentage of individuals with very narrow chests relative to their shoulder breadths, the B group percentage intermediate between A and C, and the C group with the largest percentage of boys with this disproportion. Identical patterns to the two disproportions detailed above may be seen for the following ratios: head circumference/chest circumference; chest circumference/stature; calf circumference/biacromial diameter; face breadth/chest breadth; and hand area/weight.

TABLE II

DISPROPORTIONS AND "SOUNDNESS" — A, B, C RATINGS*

Disproportions	Total Series No.	%	A Ratings No.	%	B Ratings No.	%	C Ratings No.	%
Height/$\sqrt[3]{\text{Weight}}$ 13.9-x	24/346	6.9	3/83	3.6	19/244	7.8	2/19	10.5
Biac. diam./chest circ. 47-x	79/352	22.4	8/85	9.4	66/247	26.7	5/20	25.0
Chest br./biac. diam. x-67	48/352	13.6	7/85	8.2	36/247	14.6	5/20	25.0
Chest depth/biac. diam. x-46	54/352	15.3	13/85	15.3	38/247	15.4	3/20	15.0
Bi-iliac diam./biac. diam. 76-x	84/352	23.9	18/85	21.2	62/247	25.1	4/20	20.0
Head circ./chest circ. 72-x	64/354	18.1	14/85	16.5	44/249	17.7	6/20	30.0
Chest circ./stature x-45	48/353	13.6	10/84	11.9	32/249	12.9	6/20	30.0
Calf circ./biac. diam. x-85	60/349	17.2	13/83	15.7	43/246	17.5	4/20	20.0
Face br./chest br. 55-x	53/354	15.0	6/85	7.1	40/249	16.1	7/20	35.0
Hand area/weight 128-x	56/348	16.1	9/84	10.7	43/245	17.6	4/19	21.0

* A Ratings include individuals rated A and B+, B Ratings include individuals rated B and B—.

In the case of the other three disproportions, the only pattern that seems to be consistent for all is the fact that the B group displays the highest frequency of the disproportions. For the most part, however, the differences between the percental frequencies of the A, B and C groups are very small indeed.

A conclusion, based on the frequency in 7 out of 10 disproportions, seems warranted. The C group, those who are least "sound," are the most disproportionate, in their physical structure; the A most "sound" class the least disproportionate, and the B group intermediate between A and C in the occurrence of bodily disproportions. The consistency of this pattern of relationship is most impressive and must be regarded as highly suggestive of a significant association.

A more detailed analysis of the personality groupings reveals the particular disproportions which are statistically significant in extent of their divergencies from the frequency of the total series figures. Statistical significance when used here implies a probability error level of at least 5 per cent or less. Table III compares the figures of the A "soundness" group with those of the total series. In the case of all the disproportions but one, the A group have fewer instances of disproportions than the total adolescent population. The disproportions in which the A group shows statistically significant deficiencies occur in the case of the individuals with the very wide shoulders relative to their chest circumferences, and also in those persons with very broad faces rel-

TABLE III
DISPROPORTIONS AND "SOUNDNESS" A RATINGS

Disproportions	Total Series No.	Total Series %	A Ratings No.	A Ratings %	A Ratings vs. Total Series Diff.	A Ratings vs. Total Series C.R.*
Height/$\sqrt[3]{\text{weight}}$ 13.9-x	24/346	6.9	3/83	3.6	— 3.3	1.36
Biac. diam./chest circ. 47-x	79/352	22.4	8/85	9.4	—13.0	3.24
Chest br./biac. diam. x-67	48/352	13.6	7/85	8.2	— 5.4	1.67
Chest depth/biac. diam. x-46	54/352	15.3	13/85	15.3	0	0
Bi-iliac diam./biac. diam. 76-x	84/352	23.9	18/85	21.2	— 2.7	0.67
Head circ./chest circ. 72-x	64/354	18.1	14/85	16.5	— 1.6	0.44
Chest circ./stature x-45	48/353	13.6	10/84	11.9	— 1.7	0.52
Calf circ./biac. diam. x-85	60/349	17.2	13/83	15.7	— 1.5	0.41
Face br./chest br. 55-x	53/354	15.0	6/85	7.1	— 7.9	2.34
Hand area/weight 128-x	56/348	16.1	9/84	10.7	— 5.4	1.55

* Critical ratio is in terms of standard errors and computed according to formula 19.6 of Yule, G. Udney and Kendall, M. G.: "An Introduction to the Theory of Statistics". Griffin and Co. 1937.

ative to the width of the chest. Deficiencies of probable significance (approaching the 5 per cent probability level) are to be found in those individuals with very narrow chests relative to width of shoulders and in those individuals with large hand size relative to their body weight.

In comparison with the total series frequencies, the B "soundness" group shows a statistically significant excess of individuals with very broad shoulders relative to the circumferences of the chest (Table IV). In 8 out of 10 disproportions the B ratings are in excess of the total series figures.

Table V compares the C ratings in their frequency of disproportions with those of the total series. In 8 out of 10 disproportions the C group exhibit a consistent excess of disproportionate individuals. Despite

TABLE IV
DISPROPORTIONS AND "SOUNDNESS" B RATINGS

Disproportions	Total Series No.	Total Series %	B Ratings No.	B Ratings %	B Ratings vs. Total Series Diff.	B Ratings vs. Total Series C.R.
Height/$\sqrt[3]{\text{weight}}$ 13.9-x	23/346	6.9	19/244	7.8	+0.9	1.31
Biac. diam./chest circ. 47-x	79/352	22.4	66/247	26.7	+4.3	2.97
Chest br./biac. diam. x-67	48/352	13.6	36/247	14.6	+1.0	0.84
Chest depth/biac. diam. x-46	54/352	15.3	38/247	15.4	+0.1	0.08
Bi-iliac diam./biac. diam. 76-x	84/352	23.9	62/247	25.1	+1.2	0.81
Head circ./chest circ. 72-x	64/354	18.1	44/249	17.7	—0.4	0.30
Chest circ./stature x-45	48/353	13.6	32/249	12.9	—0.7	0.59
Calf circ./biac. diam. x-85	60/349	17.2	43/246	17.5	+0.3	0.23
Face br./chest br. 55-x	53/354	15.0	40/249	16.1	+1.1	0.89
Hand area/weight 128-x	56/348	16.1	43/245	17.6	+1.5	1.17

TABLE V
DISPROPORTIONS AND "SOUNDNESS" C RATINGS

Disproportions	Total Series No.	Total Series %	C Ratings No.	C Ratings %	C Ratings vs. Total Series Diff.	C Ratings vs. Total Series C.R.
Height/$\sqrt[3]{\text{weight}}$ 13.9-x	24/346	6.9	2/19	10.5	+ 3.6	0.64
Biac. diam./chest circ. 47-x	79/352	22.4	5/20	25.0	+ 2.6	0.29
Chest br./biac. diam. x-67	48/352	13.6	5/20	25.0	+11.4	1.60
Chest depth/biac. diam. x-46	54/352	15.3	3/20	15.0	— 0.3	0
Bi-iliac diam./biac. diam. 76-x	84/352	23.9	4/20	20.0	— 3.9	0.42
Head circ./chest circ. 72-x	64/354	18.1	6/20	30.0	+11.9	1.25
Chest circ./stature x-45	48/353	13.6	6/20	30.0	+16.4	2.20
Calf circ./biac. diam. x-85	60/349	17.2	4/20	20.0	+ 2.8	0.34
Face br./chest br. 55-x	53/354	15.0	7/20	35.0	+20.0	2.58
Hand area/weight 128-x	56/348	16.1	4/19	21.0	+ 4.9	0.52

the small size of this C group, statistically significant excesses are to be found in the case of persons with very small chests relative to their stature, and in the individuals with very broad faces relative to the width of the chests. The disproportion of chest breadth relative to shoulder breadth approaches the 5 per cent level of statistical significance.

Further confirmation of the existence of an association between disproportions and degrees of "soundness" of the personality is to be found in the comparison of the A and C groups in Table VI. In com-

TABLE VI
COMPARISON BETWEEN A AND C RATINGS*

Disproportions	A Ratings No.	A Ratings %	C Ratings No.	C Ratings %	Diff.	C.R.*
Height/$\sqrt[3]{\text{weight}}$ 13.9-x	3/83	3.6	2/19	10.5	+ 6.9	1.07
Biac. diam./chest circ. 47-x	8/85	9.4	5/20	25.0	+15.6	1.51
Chest br./biac. diam. x-67	7/85	8.2	5/20	25.0	+16.8	1.97
Chest depth/biac. diam. x-46	13/85	15.3	3/20	15.0	— 0.3	0
Bi-iliac diam./biac. diam. 76-x	18/85	21.2	4/20	20.0	— 1.2	0.11
Head circ./chest circ. 72-x	14/85	16.5	6/20	30.0	+13.5	1.41
Chest circ./stature x-45	10/84	11.9	6/20	30.0	+18.1	2.12
Calf circ./biac. diam. x-85	13/83	15.7	4/20	20.0	+ 4.3	0.46
Face br./chest br. 55-x	6/85	7.1	7/20	35.0	+27.9	3.15
Hand area/weight 128-x	9/84	10.7	4/19	21.0	+10.3	1.10

* Critical ratio is in terms of standard errors and computed according to formula 19.4 of Yule, G. Udney and Kendall, M. G.: "An Introduction to the Theory of Statistics". Griffin and Co. 1937.

parison with the "most sound" adolescents of the A group, the "least sound" boys of the C group show statistically significant excesses of individuals with the following disproportions: chests very narrow for width of shoulders, chest size very small for body height; and faces very broad for width of chest.

DISCUSSION

The results of the analysis of the body disproportions of an unselected series of adolescent males in their ninth grade of school, indicate an association between certain unilateral restricted ranges of body ratios called *disproportions* and differential overall ratings of the general "soundness" of the personality. It was found that the disproportions were consistently more frequent in the "less sound" individuals and least frequent in the "most sound" boys. The C personality group showed a statistically significant excess of individuals with very small

chest circumferences relative to their statures, and with very broad faces relative to the width of their chests. The A personality group, on the other hand, exhibited a significant deficiency of individuals with very wide shoulders relative to their chest circumferences, and with very broad faces relative to the width of their chests. These general findings are in consonance with previous studies made in connection with this element of disproportions, and serves to confirm the existence of a relationship between physique and personality.

It should be emphasized, however, that these body disproportions are not to be regarded as implying any stigma of abnormality. These ratios are not in any sense abnormal, but simply normal deviates from the mean of the group as a whole, albeit extreme deviates. Similarly, the C group or "least sound" individuals are not abnormal or "defective" personalities, but represent individuals who are on the whole relatively more sensitive, more complex, less well integrated, and with a lesser capacity for making easy social adjustments. Furthermore, the disproportions themselves are too subtle for the unprofessional eye, and scarcely so pronounced as to interfere with normal activities or for that matter in the indulgence of sports. It is possible, however, that they may dictate to some extent the particular variety of sport in which the youngster may prefer or in which he may excel.

All indications point to the conclusion that the disproportions are constitutional in nature and as such their relationship to personality suggest the presence of a genetic element in the determination of personality and behavior. Moreover, the findings in this study accentuate the need for an extensive study of the nature and selection of the disproportions and their relationship to body function and behavior.

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Growth, 1959, **23**, 13-19.

THE EFFECT OF MAMMALIAN THYROID POWDER ON OXYGEN CONSUMPTION IN LEBISTES RETICULATUS[1]

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(Received January 26, 1959.)

THE effect of the thyroid gland on metabolic activities of warm-blooded animals is well established. However, attempts to assign a role to the thyroid gland of cold-blooded forms similar to that which it plays in birds and mammals have generally yielded negative or controversial results. Some investigators have reported completely negative results of thyroid influence on growth and differentiation (Smith and Everett, 1943). Grobstein and Bellamy (1939) reported a positive effect on differentiation and a negative effect on growth. Presumptive evidence for a positive effect on growth was introduced by Goldsmith *et al.* (1944) who reported that thiourea inhibited growth in Platypoecilus-Xiphophorus hybrids and Nigrelli, Goldsmith and Charipper (1946) further strengthened this evidence by overcoming the inhibitory effects of thiourea with mammalian thyroid powder. Hopper (1952) reported that Lebistes raised in solutions of mammalian thyroid powder grew more rapidly and matured earlier than control fish and interpreted the data as clear-cut evidence that the thyroid hormone in the guppy has a positive effect on both growth and differentiation.

A number of studies have dealt with oxygen consumption of thyroid-treated fish. Root and Etkin (1937) reported no change in oxygen consumption after injecting thyroxine into 5 toadfish. Similar results have been reported by Etkin, Root and Mofshin (1940) after feeding thyroid powder to goldfish, Hasler and Meyer (1942) after injecting thyroxine into Fundulus, and Mathews and Smith (1947) after injecting thiourea into Fundulus. A single positive report is that of Smith and Mathews (1948) who extracted the compact thyroid gland of the parrot fish, injected this extract into Bathystoma and noted a significant rise in oxygen consumption in fish weighing more than 16 grams but not in those weighing less. Smith and Brown (1952) were

[1] Supported by a grant from the National Science Foundation.

able to show that parrot fish thyroid extracts were capable of increasing oxygen consumption in the rat.

In view of the facts that teleostean thyroid extract will increase oxygen consumption in the mammal and that the same extract will increase oxygen consumption in some fish and despite the numerous negative results, we felt it worthwhile to continue the experimentation on oxygen consumption in fish using a method of administration of the thyroid compound which has been previously shown to have a positive effect on growth and differentiation. The experiments reported in this paper give evidence for a stimulating effect of mammalian thyroid powder on oxygen consumption in the guppy.

Materials and Methods

Mature female guppies were kept in 3000cm^3 aquaria and 0.3gm (0.01%) of mammalian thyroid powder was thoroughly mixed with the water before the fish were introduced. The water was changed and the hormone renewed twice each week. All fish were maintained under these conditions for at least 45 days before oxygen consumption measurements were made.

For the determination of oxygen consumption, individual fish were placed in glass tubes 6cm x 2cm and conditioned tap-water passing through these tubes was collected in two bottles. Oxygen content of the water before and after passing through the tubes containing the fish was determined by the Winkler technique, the average of the two collecting bottles being used. The flow rate was adjusted to approximately 70 ml/hour. Fish were placed in the tubes in the morning, left in overnight and oxygen determinations were made the following morning. Thus the determinations were always made on water which had passed through the tubes while the fish were in the dark and undisturbed.

Control fish were females of approximately the same weight as the experimentals. All fish were weighed at the conclusion of each experiment. No fish, neither control nor experimental, was used in more than a single experiment.

Statistical formulae used in the analysis of the data were:

$$s = \text{standard deviation} = \sqrt{\frac{\Sigma d^2}{n - 1}}$$

$t = \bar{x}\sqrt{\frac{n(n-1)}{S_x 2}}$, where $\bar{x}$ is the difference between the means and $S_x 2$ is the pooled sum of the deviations squared

$t = \frac{\bar{x}-m}{S_{\bar{x}}}$, where $\bar{x}$ is the calculated mean, m is the expected mean and $S_{\bar{x}}$ is the standard deviation of the mean.

Results

The uptake of oxygen per kilogram per hour is shown in Table I. For thyroid-treated fish the range is from 233ml to 426ml with an average uptake of 321 ± 21.4 and for controls the range is from 114ml to 355ml with a mean of 279 ± 21.6. Statistical analysis gives a t-value of 2.14 for which $0.05 > p > 0.02$ and the data are therefore significant at the 95% level of confidence. The variation in any one group is large and this may be due to a variety of causes. The experiments were conducted in a laboratory in which the temperature was not uni-

TABLE I
Oxygen Consumption of Thyroid-Treated and Control Fish

Part No.	Thyroid[1]	Control[1]	T/C ratio
1	239	302	0.80
2	352	345	1.01
3	363	355	1.01
4	292	365	0.80
5	317	114	2.80
6	307	218	1.40
7	391	355	1.10
8	230	165	1.40
9	256	215	1.20
10	318	197	1.62
11	377	356	1.02
12	260	260	1.00
13	329	283	1.08
14	286	230	1.20
15	276	295	0.94
16	233	245	0.95
17	274	250	1.10
18	418	354	1.18
19	420	310	1.36
20	267	219	1.28
21	244	328	0.77
22	426	271	1.58
23	420	332	1.26
24	407	328	1.24

[1] Figures represent ml oxygen/kg/hr.

form. No effort was made to control the water temperature since we were not interested in individual oxygen consumptions per se but in comparisons between controls and experimentals. Flow rates and weights of fish differed from experiment to experiment, although weights of any two fish in a single experiment and the flow rates in any single experiment were as alike as could be controlled. Fish were purchased at different times from different dealers and individual differences may thus have been introduced. Although the range is large in both groups, high oxygen uptake by a fish in one group is generally paralleled by a high uptake by the paired fish in the other group. If we assume that due to the experimental error these data do not represent a normal distribution and apply the square root transformation before determining the t-value, the results are still significant at the 95% level ($t=2.21$).

Table I also shows the ratios of the thyroid-treated to the control fish (T/C) for the individual pairs of fish and this may be a more accurate representation of the differences in oxygen consumption. The average ratio of thyroid-treated to control fish is 1.21 ± 0.47. The t-value for this mean, assuming an expected ratio of 1.0 if the thyroid powder were without effect, is 2.18 which is again significant at the 95% level of confidence. Only 5 of the 24 pairs show a T/C ratio of less than 1 and if we assume a 5% experimental error, 4 pairs show a decrease, 5 show no change and 15 show an increase in oxygen consumption following treatment with thyroid powder.

Discussion

The phylogeny of the thyroid gland from the protochordates to the mammals is established. It was early assumed without experimental justification that the thyroid hormone served the same functions throughout the vertebrate phyla with certain specific functions in such forms as the amphibians. If, in examining the question of functional similarity, we assume analagous effects of the thyroid hormone in fish and mammals, we must thus look for a calorogenic, a growth and a maturation effect in the lower vertebrates. Review of the papers on the function of the teleost thyroid shows a variety of negative, positive and contradictory results. However, there is a slowly accumulating body of evidence that gives positive indication for a similarity of function in teleosts and mammals. Histologically, thyroid follicles in mammals and teleosts are similar and show paralleling changes in

hypo- and hyperfunctioning of the tissue. Uptake and storage of radioiodine occurs in both phyla. Thiourea inhibits teleostean growth (Goldsmith *et al.*, 1944) and this inhibition may be overcome by mammalian thyroid powder (Nigrelli, Goldsmith and Charipper, 1946). Young fish raised in solutions of mammalian thyroid powder show an increased growth rate (Hopper, 1952). A positive effect on maturation, indicated by an earlier differentiation of the gonopodium, has been reported by Grobstein and Bellamy (1939) in Platypoecilus and Hopper (1952) in Lebistes. Teleost thyroid extract will increase oxygen consumption in mammals (Smith and Brown, 1952). However, the only report indicating an increased oxygen consumption in fish as the result of treatment with mammalian thyroid substances is that of Smith and Mathews (1948) and since the positive effect was observed only in larger fish, the authors did not advance these results as supporting any general conclusions. The data reported in the present paper now give evidence that mammalian thyroid powder can increase oxygen consumption in the guppy. Thus, a variety of investigations offer support to the conclusion that the teleostean thyroid, as the mammalian, serves a growth, a maturation and a calorogenic function.

We may ask the reason for the many negative reports on oxygen consumption. The type of substance administered may be important. Thyroxin, either injected or added to the aquarium water, has never produced any positive effect on growth, differentiation or oxygen consumption. The teleost may be insensitive to the compound. Mammalian thyroid powder may be given either by feeding or by mixing with the water. Although fish will ingest thyroid powder spread on the surface of the water, this method of administration is not as effective as mixing the powder with the aquarium water (Hopper, unpublished). However, feeding thyroid powder has stimulated growth (Nigrelli, Goldsmith and Charipper, 1946) and gonopod differentiation (Grobstein and Bellamy, 1939). The latter authors also reported a 12% increase in oxygen consumption in treated fish although this increase was not significant. Immersing the fish in solutions of thyroid powder seems to give the most uniform results. All fish so treated show within two weeks the characteristic elongated and pointed fins and bilateral exophthalmia which give evidence that the compound is producing an effect. In those experiments in which these easily recognized and reproducible responses are not developed we should perhaps not expect to find other effects on growth, differentiation or oxygen

consumption. All fish used in our experiments showed marked exophthalmia and fin elongation. Feeding thyroid powder to young fish does not produce as marked exophthalmia or fin elongation nor does it take effect as quickly (Hopper, unpublished). The type of compound administered and the method of administration are thus important to the end result and should be taken into account when evaluating the effects of treatment of teleosts with mammalian substances. The results in this report demonstrate that oxygen consumption in the guppy can be elevated by immersing the fish in solutions of mammalian thyroid powder and we believe that these data added to the previous reports outlined above give evidence for a similarity of function of the teleostean and mammalian thyroid glands.

Summary

1. Mature female guppies were maintained in 0.01% solutions of mammalian thyroid powder for 45 days.

2. These females showed an increased oxygen consumption—average 321ml/kg/hr—over mature control females of comparable size—average 279ml/kg/hr—representing a 15% increase.

3. The average ratio of oxygen consumption of thyroid-treated fish to controls was 1.21 and only 5 of 24 pairs of fish tested consumed more oxygen than their experimental partners.

4. The data are interpreted as evidence for a positive effect of the teleostean thyroid on oxygen consumption.

5. The role of the teleostean thyroid is discussed.

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Growth, 1959, **23**, 21-27.

CHANGING SPECIFICITY OF CANCEROUS TISSUE BY INTRA-OCULAR TRANSPLANTATION

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(Received February 16, 1959.)

THE history of intra-ocular heterologous transplants of cancerous tissue may be divided logically into three eras. (Morris, *et al.* (4)).

The first era, 1884-1912, was a period of agreement among investigators on the nontransplantability of tumors from one species to another. The second era, 1913-1937, was a period of dissension. There was a report of successful heterologous transplantation into the anterior chamber of the eye, but regression occurred later after an unstated period. The third era, 1937 to the present, has been a period of general agreement on the heterotransplantability of malignant tumors, with ideas diametrically opposed to those of the first era. Greene (1) has reported the successful heterologous transplantation of tumor tissue of the rabbit into the anterior chamber of the eye of the guinea pig.

Early genetic studies with transplantable tumors led to the formation of certain laws of transplantation which were stated by Snell (2) as follows:

"1. Tumor isotransplants, i.e. tumors transplanted within the strain of origin, grow progressively and kill all hosts.

"2. Tumor homoiotransplants, i.e. tumors transplanted within the species but outside the strain of origin, fail to grow, or grow only temporarily and then regress.

"3. F_1 hybrids produced by crossing two inbred strains will grow tumors indigenous to either parent strain.

"4. Only a fraction of mice of an F_2 generation, or of a backcross produced by mating the F_1 to the resistant parent, will grow tumors from the inbred lines involved. The portion susceptible

* Submitted as a part of the trainee program of the Biological Station of Roswell Park Memorial Institute in cooperation with Griffith Institute and Central School, Springville, N. Y. The advice and assistance rendered to the author by Dr. Leonell C. Strong and Mr. L. B. Hardy is greatly appreciated.

may be large or small, depending on the tumor and the cross, but rarely exceeds 75% for the F_2 or 50% for the backcross."

According to Strong (6), there are at least eight ways by which tumor-host relationships can be altered, thus permitting tumors derived from one strain of experimental animal to grow progressively when transplanted into individuals of other strains or even species. These are as follows:

1. X-raying mice before the transplantation of the tumor.
2. Mixing a tumor with cotton or wool fiber before transplantation.
3. Growing a tumor in an F_1 mouse. This observation is based partly on the fact that susceptibility to transplanted tumors is dominant in crossing tests.
4. The ageing of tumors through numerous transplant generations permits successive changes to take place; that is, adapted changes take place spontaneously.
5. The treatment of the host by tumor or normal tissue extracts before the inoculation of the tumor.
6. The treatment of host by estrogenic hormones before the injection of the tumor.
7. The growth of tumors in the newborn.
8. Growing a tumor in the anterior chamber of the eye or in the brain.

To these methods of altering cancer susceptibility can also be added the use of cortisone.

It is the purpose of the present experiment to attempt to change the histiocompatability relationships of four strain-specific tumors to enable them to grow in a completely unrelated foreign species by serial transplantation in the anterior chamber of the eye of the guinea pig.

Materials and Methods

The guinea pig eye is used as the site for transplant because it is readily accessible and the amount of eventual tumor growth can also be observed in this site by gross inspection. The transplant technique is similar to that used by Greene (1).

The guinea pigs were etherized in preparation for the reception of the transplants. The eye, into which the tumor was to be placed, was steadied with the left hand. With the right hand, an incision was made just above the corneo-sclerotic junction, using a sharp thin blade.

Through the incision, using a pair of fine serrated forcepts, a piece of tumor tissue derived from a mouse was placed into the anterior chamber above the inferior angle of the iris. After this procedure, some of the animals were injected with 15 mg. of cortisone, subcutaneously.

The reason for the use of the cortisone is that stated by Foley, *et al.* (5):

"The nature of the change in resistance shown by these experiments has not been established, but it might be inferred that it is associated with the well known depression of normal lymphoid tissue and immune responses which large doses of cortisone induce."

In about seven days when the tumor grows it completely fills the anterior chamber of the eye. At this time the transplant is recovered for transplantation into the eyes of other guinea pigs. At the same time, the tumor is tested by transplantation into mice of the strain of origin, and in the case of the pBr tumor into mice of a foreign strain which would not, under normal conditions, support the growth of that particular tumor. The strain-specific tumors used in this experiment were derived from the dba, C_3H, A, and pBr strains.

The guinea pigs used in this experiment were housed in stainless steel cages with about six animals to a cage. The animals were fed Purina Guinea Pig Chow supplemented with a mixture of grains. This diet was further supplemented by fresh greens twice a week. The animals received water *ad libitum*.

Results

According to the data presented in Table I, the dba, C_3H, and A mouse tumors grew 100% when transplanted into the anterior chamber of the guinea pig eye, but were always accompanied by a large amount of sterile inflammatory material; that is, material that probably could have arisen from a sterile technique. This aberrant tissue may be the

TABLE I

Results of Several Strain Specific Tumors Transplanted Serially into the Anterior Chamber of the Guinea Pig Eye

Strain of Tumor Origin	Number of Guinea Pigs Transplanted	Number Positive	Number Negative	Percent Positive	Number of Serial Transplant Generations
dba	70	70	0	100	28
C_3H	28	28	0	100	14
A	30	30	0	100	15

result of necrotic cancerous tissue. It is well known that many rapidly growing tumors undergo necrosis. In the transplants of the pBr tumor (an anaplastic carcinoma) only 75% grew in the eye of the guinea pig and 35% of these regressed shortly after one week of poor growth (Table II).

Material from the eye, when transplanted back into mice of the original strains, appeared to grow poorly, but then eventually regressed (Table III). When the mice were autopsied the growth seemed to contain inflammatory material with very little, if any, tumor tissue.

On the other hand, when the tumor transplants into the eye were accompanied with subcutaneous injections of cortisone this inflammatory material was not present. The same results were obtained when the tissue was transferred from the guinea pig to mice. That is, no inflammation was present, but neither was there any evidence of tumor growth. The tumor tissue growing in the eye in cortisonized animals did not regress so readily as in the control or untreated mice.

Tissue taken from the eyes of untreated guinea pigs, which were implanted with pBr tumor, was transplanted into some mice of the F strain, which is completely unrelated to the pBr strain. The results of this test were negative; none of the F mice grew the tumor.

Discussion

The fact that there was growth in the mice transplanted from the tumor mass in the eyes of guinea pigs not injected with cortisone might be due to some sort of inflammation which arose during one of the transplant generations and was carried serially to the succeeding transplant generations. This would mean that inflammatory tissue was transplanted into the mice and persisted, thus inhibiting the growth of the tumor tissue.

A rational reason for the absence of growth in the mice transplanted from cortisone injected guinea pigs could be that the injecting of cortisone into the guinea pig host eliminated the inflammatory material. This was due to the inhibitory effect of cortisone upon the hemapoetic tissue which produce anti-bodies. This treatment made it possible to observe more readily the presence and growth of the cancerous tissue. When the tumor grew in the anterior chamber of the guinea pig eye, it was growing in a different environment and a different species. Having grown under these conditions the tumor might have changed its ability to grow in mice of its originating strain.

TABLE II

SERIAL TRANSPLANTATION OF pBr TUMOR INTO THE GUINEA PIG ANTERIOR CHAMBER WITHOUT THE AID OF CORTISONE

pBr Tumor into Guinea Pig	First Week Positive	First Week Negative	Percent Positive	Total	Second Week Positive	Second Week Negative	Percent Positive
Transplant 1	14	5	74	19	7*	11	39
Transplant 2	6	9	40	15	1*	13	7
Transplant 3	1	2	33	3	0	3	0
Total 3 Tumor Generations	21	16	57	37	8*	27	29

* It will be noted that the number in the second week is less than the total due to the sacrifice of animals for continued transplantation.

TABLE III

SERIAL TRANSPLANTATION OF pBr TUMOR INTO THE GUINEA PIG ANTERIOR CHAMBER WITH THE AID OF CORTISONE

pBr Tumor into Guinea Pig	First Week		Percent		Second Week		Percent
	Positive	Negative	Positive	Total	Positive	Negative	Positive
Transplant 1	3	0	100	3	2*	0	100
Transplant 2	2	0	100	2	1*	0	100
Transplant 3	2	0	100	2	1*	0	100
Total 3 Tumor Generations	7	0	100	7	4*	0	100

* The number in the second week is less than the total due to the sacrifice of animals for continued transplantation.

The fact that tumor tissue, transplanted to the guinea pig eye from the pBr mouse, would not grow in the F mouse is of little significance because of the inability to demonstrate growth of the tumor in the strain of origin.

Summary

The growth of an anaplastic carcinoma of the pBr mouse in the anterior chamber of the eye of a foreign species, a common method by which the specificity of many transplantable tumors has been altered, failed to alter its behavior. In the present experiment, transplantable tumors of the dba, C_3H, and Strong A strains of mice have been continued for several serial passages in the eyes of guinea pigs and then back into mice. The pBr anaplastic carcinoma which is unique by not having the capacity to alter its characteristics by means which have altered other transplantable tumors, is also unique in not growing well in the anterior chamber of the eye of the guinea pig. Many of these intra-ocular grafts eventually regress. Part of this failure to grow, however, may be due to a peculiar inflammatory reaction which the tumor elicits when grafted. Most of this complicating factor of inflammation can be avoided by cortisoning the host which has received the transplant of the anaplastic carcinoma.

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Growth, 1959, **23**, 29-35.

THE RECOVERY OF BEEF CATTLE FROM MOLYBDENUM TOXICOSIS AS INFLUENCED BY DIFFERENT ROUGHAGES[1]

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(Received February 16, 1959.)

MOLYBDENUM toxicity in cattle has been observed in a number of areas in Nevada. These areas are concentrated in western and southern Nevada (Dye, 1958) and include primarily irrigated valleys and mountain meadows although some ranges are involved as well. Many of these pastures are not conducive to the usual methods of copper therapy. Copper salts cannot usually be added to the drinking water successfully because of poor drainage and the source of drinking water cannot be controlled. Soil salinity is often a problem in these areas and as a result many plants and even the water itself contain more sodium chloride than the animal requires for its nutritional needs. Hence the mixture of copper salts in sodium chloride and other mineral mixtures does not insure an adequate supply of copper to meet the increased needs of the animal. Copper could be supplied in a feed pellet or by injection as copper glycinate (Cunningham, 1957) but these treatments are not used extensively at the present time. Consequently, some cattle are produced annually with typical symptoms of molybdenum toxicity such as anemia, achromatrichia, scouring and rough hair coat. When marketed, these animals are discriminated against because of their appearance.

The purposes of this study were (1) to measure the recovery of weanling beef cattle from molybdenum toxicosis as influenced by different roughages and evidenced by growth and blood data and (2) to compare the response of molybdenum-poisoned cattle to other animals during their recovery period.

[1] This work was supported in part and in cooperation with the regional project W-34, Range Livestock Nutrition and with Nevada project, Hatch 47. It was conducted at the Knoll Creek Range Station in Elko County in cooperation with the Bureau of Land Management.

Experimental Procedure

Forty weanling Hereford calves were obtained from Southern Nevada with typical symptoms of molybdenum toxicity. Forage samples collected from the general area in which these cattle had grazed contained 2 to 20 ppm molybdenum (Dye, 1958). These animals were matched according to weight and allotted at random to four roughage treatments. The treatments included intermediate wheatgrass and native hay with and without a roughage supplement of mixed alfalfa-brome grass. During the first half of each feeding period, the first cutting of alfalfa-brome grass hay was used; during the second half, the second cutting was fed. The proportions of alfalfa to brome were approximately equal in the first cutting. The second cutting was nearly 100% alfalfa. The average chemical composition of these two cuttings of alfalfa-brome and the average composition of the other forages is given in Table I. The native hay was composed of the following: Juncus spp., Carex spp., Deschampsia spp. and other minor components.

TABLE I
The Composition of the Experimental Roughages (Bohman)

	Percent of the Dry Matter				ppm	
Roughage	Protein	Ether Extract	Crude Fiber	P	Mo	Cu
1956-57						
Intermediate Wheatgrass	6.66	2.48	36.53	0.20	1.3	4.2
Native	8.56	2.04	33.68	0.19	2.2	5.6
Alfalfa-Brome	13.22	1.78	34.04	0.22	3.3	6.8
1957-58						
Intermediate Wheatgrass	7.28	2.64	37.99	0.22	0.9	7.1
Native	8.82	2.18	33.40	0.18	3.1	5.9
Alfalfa-Brome	15.26	2.01	32.62	0.24	3.5	6.6

Initially, blood samples were taken from one-half of the animals for comparisons of the total cell and hemoglobin levels with cattle of similar weight and normal appearance from both southern and northern Nevada. At the end of a 129 day feeding period, these same 20 cattle were resampled for the determination of these two blood constituents. Blood analytical procedures were the same as those described earlier by Bohman and Wade (1958). Growth data were obtained from all of the animals.

The following year the experiment was repeated with the following modifications: half of the cattle were from a typical northern Nevada range, while the balance were from the same molybdenum area in southern Nevada, only the hematocrit was determined on the blood but it was determined on the entire 40 animals; the feeding period was 122 days. The hematocrit was determined by centrifuging a capillary tube of whole blood for 30 minutes at 2400 RPM and reading the % red blood cells. All data were subjected to statistical analyses according to methods described by Snedecor (1956).

Results and Discussion

A comparison of blood hemoglobin and total cell count of weanling beef cattle from different areas is shown in Table II. Cattle that had

TABLE II
A Comparison of Blood Hemoglobin and Total Cell Count of Weanling Beef Cattle From Different Areas[b] (Bohman)

Location	Total cell count millions/mm^3	Hemoglobin gms./100 mls.
Northern Nevada (Lamoille area)	7.56	14.92
Southern Nevada (Delamar Valley)	6.87[a]	14.02[a]
Southern Nevada—Mo— (Pahranagat Valley)	6.02*	12.27*

* Significantly different from animals from other locations.
[a] Difference between these values and values from northern Nevada approaches significance.
[b] All cattle sampled December 7 and 8, 1956.

consumed forage containing an excess of molybdenum had significantly lower levels of total cells and hemoglobin than cattle from either of the other range areas. This has been described earlier by others (Britton and Goss, 1946; Cunningham *et al.* 1953).

The growth of the experimental cattle was markedly influenced by the type of roughage consumed each year (Tables IV and V). The rate of gain was greatest when alfalfa was fed as a supplement to either native grass hay or wheatgrass hay. During the first year alfalfa increased the rate of gain the same amount with both grass hays. During the next year the growth rate was improved much more when alfalfa was fed with wheatgrass rather than native hay. This interaction was statistically significant. Alfalfa also increased the total feed consumption.

Wheatgrass hay was not as adequate for growth as native hay. This difference existed whether alfalfa was included in the ration or not.

Cattle from the molybdenum area grew just as rapidly as normal cattle (Table IV). Their previous treatment appeared to have no effect on their subsequent rate of gain. Bohman (1955) and Bohman and Torell (1956) have studied retarded growth in beef cattle. In those studies animals with retarded growth in one period accelerated their growth rate in a following period. Early experiments with laboratory animals (Osborne and Mendel, 1915) have shown that following a period of retardation, growth in weight can be resumed at a more rapid rate than normally exhibited at any time during life. In the current study, the calves did not accelerate their growth when excess molybdenum was removed from their diet.

TABLE III

THE EFFECT OF DIFFERENT ROUGHAGES ON WEIGHT CHANGES AND TOTAL CELL AND HEMOGLOBIN CONTENT OF BLOOD OF WINTERING BEEF CATTLE (1956-1957) (Bohman)

Basal roughage	Native Grass Hay		Wheatgrass Hay		
Supplemental roughage	None	Alfalfa-brome	None	Alfalfa-brome	Average
Average		pounds			
Initial wt. 12/4/57	348.0	347.5	347.5	356.	349.8
Final wt. 4/13/57	430.0	478.2	408.2	477.8	448.5
Daily gain (129 days)	0.64[a]	1.01[cg]	0.47	0.94	0.76
Daily feed consumed					
Grass hay	9.78	6.62	10.82	6.67	
Alfalfa-brome		6.42		6.25	
Total	9.78	13.02	10.82	12.92	
		millions/mm^3			
Initial total cell	6.20[b]	6.39	5.97	5.52	6.02
Final total cell	7.66[d]	7.86	6.29	7.02	7.21**
Change total cell	1.46	1.47[e]	0.32[f]	1.50	1.19
		gms/100 mls.			
Initial Hb.	12.28[b]	12.98	12.10	11.72	12.27
Final Hb.	14.94[g]	15.82	13.12	13.74	14.40
Change in Hb.	2.66[g]	2.84	1.02	2.02	2.13

[a] 10 animals per group.
[b] 5 animals per group.
[c] Alfalfa treatments are significantly different from grass alone $P < .01$.
[d] Differences between the two grasses approaches significance $P < .05$.
[e] Alfalfa treatments are significantly different from the grass alone $P < .05$.
[f] Significant type of grass X alfalfa interaction.
[g] Differences between the two grasses significant at $P < .01$.
** Differences are significant at $P < .01$.

TABLE IV
THE EFFECT OF DIFFERENT ROUGHAGES ON WEIGHT CHANGES OF WINTERING BEEF CATTLE (1957-1958) (Bohman)

Basal roughages	Wheatgrass Hay		Native Hay		
Supplemental roughage	None	Alfalfa	None	Alfalfa	Average
Av. initial weight 11/18/57					
Southern Nevada	367.6	369.4	369.4	372.6	369.8
Northern Nevada	376.8	359.8	368.0	370.6	368.8
Avg.	372.2	364.6	368.7	371.6	369.3
Av. final weights 3/19/58					
Southern Nevada	401.5	454.0	458.0	481.0	448.6
Northern Nevada	403.5	441.0	452.5	471.0	442.0
Avg.	402.5	447.5	455.2	476.0	445.3
Av. daily gain 11/18/57-3/19/58 (122 days)					
Southern Nevada	0.28	0.69	0.73	0.89	0.65
Northern Nevada	0.22	0.67	0.69	0.89	0.65
Avg.	0.25	0.68	0.72	0.86[abc]	0.62
Av. daily feed, consumed, lbs.					
Grass hay	8.97	5.82	10.04	7.18	
Alfalfa-brome		5.04		4.99	
Total	8.97	10.86	10.04	12.17	

[a] Steers fed native hay gained significantly faster than the cattle fed wheat grass at $P < .01$.
[b] Steers supplemented with alfalfa gained significantly faster than grass alone.
[c] Alfalfa X type of grass interaction significant at $P < .01$.

TABLE V
THE EFFECT OF DIFFERENT ROUGHAGES ON THE HEMATOCRIT OF WEANLING STEERS (Bohman)

Basal roughage	Wheatgrass hay		Native hay		
Supplemental roughage	None	Alfalfa	None	Alfalfa	Average
Average					
Initial hematocrit, %					
No. Nevada	38.2	37.2	37.5	35.7	37.2**
So. Nevada (Mo)	36.0	34.2	32.8	31.3	33.6
Final hematocrit, %					
No. Nevada	31.0	32.4	31.4	30.6	31.4
So. Nevada (Mo)	28.6	31.8	32.0	32.8	31.3
Hematocrit change, %					
No. Nevada	—7.2[abc]	—4.8	—6.1	—5.1	—5.8**
So. Nevada (Mo)	—7.4	—2.4	—0.8	1.5	—2.3

** Difference is significant at $P < .01$.
[a] Difference between types of grasses is significant at $P < .01$.
[b] Alfalfa supplemented groups statistically different than grasses alone ($P < .05$).
[c] Significant origin X type of grass interaction ($P < .05$).

In fact, the growth rate of the calves from the toxic molybdenum area is strikingly similar to apparently normal calves. It is perhaps possible that the different genetic background of the two groups might have obscured this effect although it is not likely.

The effect of the different roughages on blood composition is shown in Tables III and V. The first year all treatments increased the levels of total cells and hemoglobin but not to the same extent. The increase was greater when either native hay or alfalfa was fed. The second year cattle from the molybdenum area had lower initial hematocrit levels than normal cattle. However, contrary to the results of the previous year the hematocrit levels decreased during the winter period. The severity of the observed molybdenum toxicity symptoms were greater the first year in comparison to the second which may have influenced these results. Bohman *et al.* (1959) have shown that when native grass hay is fed alone to weanling beef calves, it will not maintain the level of hemoglobin or total cells in their blood under usual conditions. The change in hematocrit was influenced by both the dietary treatments and the previous history of the animals. The hematocrit of cattle from northern Nevada decreased more than cattle from southern Nevada (previous Mo exposure). At the end of the experimental period the hematocrit of the two groups was approximately equal. The decrease was not as great when either native hay or alfalfa was fed in comparison to wheatgrass alone.

The main difference in composition of the experimental roughages was their protein content. Neither molybdenum or copper levels of the experimental roughages differed enough to account for the differences in either growth or blood composition. Although the copper requirement of the animal for growth is influenced by several factors such as level of molybdenum, sulfate, etc. in the diet, it is unlikely that either a simple or induced copper deficiency existed in this study. While wheatgrass hay contained less copper on the average than the other forages, it also contained less molybdenum. It is of interest that the level of molybdenum in the native hay and alfalfa were approximately the same as that described by Ellis *et al.* (1958) to be necessary to give a growth response with sheep. Protein is one of the main "building stones" for hemoglobin synthesis and if it is not supplied in adequate amounts anemia will result. Wheatgrass hay contained less protein than any of the other roughages. It also contained more fiber. The difference in protein content of the hays is probably the most important factor influencing the growth and composition of the blood of the experimental cattle. The recovery of cattle from molybdenum toxicosis appears to be completely dependent upon nutrients subsequently available. Molybdenum toxicity does not appear to have per-

manent effects by the criteria used. After an experimental period, blood and growth data of both a normal group and a group of cattle previously showing symptoms of molybdenum toxicity were similar.

SUMMARY

During two years weanling calves from a molybdenum area have been fed two grass hays, wheatgrass and native, with and without supplemental alfalfa-brome grass hay. Alfalfa and native hay have consistently improved the growth rate and blood composition of these cattle in comparison to a diet of wheatgrass. The higher levels of protein of these two hays appear to be main factor influencing the above changes.

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OÖGENESIS IN ADULT *DROSOPHILA MELANOGASTER*
VIII. The role of folic acid in oögenesis[1]

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(Received April 8, 1959.)

INTRODUCTION

IT is known from the work of J. J. Freed, summarized by Schultz (1956), that nurse cell nuclei of *Drosophila melanogaster* undergo a series of endomitotic doublings of DNA. These doublings produce chromosomes whose multiple strands become more and more loosely associated as the nurse cell nucleus develops. The developing egg chambers of females homozygous for the female sterile mutation *singed*^{36a} show abnormalities in the synthesis of DNA and of yolk. The Feulgen-positive material in the nurse cell nuclei is reduced in amount and abnormal in distribution (King & Burnett, 1957). Six day old *sn*^{36a} females lay atypical eggs which contain about 2/3rds the usual quantity of yolk. These facts suggest that vitellogenesis cannot proceed to completion without the normal elevated chromosomal complement in the nurse cell nuclei. Three other findings implicate the nurse cell nuclei in the formation of yolky ooplasm.

1. If female flies are fed for one hour on dead yeast containing uridine-H^3 and autoradiographs are made of sections of the ovary, tritium appears first in the nurse cell nuclei; and subsequently in the nurse cell cytoplasm and ooplasm as well, but at lower concentrations (King & Burnett, 1959). These findings suggest that RNA synthesis occurs in the nurse cell nucleus and that subsequently nuclear RNA enters the cytoplasm of the nurse cell and the ooplasm. Levenbook, Travaglini & Schultz (1958) have shown that RNA makes up 2% of the ooplasm of laid, unfertilised, *Drosophila* eggs.

2. The rate of DNA synthesis in nurse cell nuclei reaches a maximum just prior to vitellogenesis (Jacob & Sirlin, 1959).

[1] This study is part of a collaborative programme carried out during the tenure by R. C. King of a National Science Foundation Postdoctoral Fellowship while on leave from Northwestern University.

3. Bodies are emitted from nurse cell nuclei as yolk formation begins (Hsu, 1953; King & Devine, 1959).

One approach to a more direct proof of the key role of nucleic acids in yolk formation is by interference with nucleic acid synthesis in normal adults. Since folic acid is necessary for the methylation of the pyrimidine ring to form thymine from uracil and for the introduction of carbon atoms 2 and 8 into the purine ring, omission of this vitamin from the adult diet might be expected to lower the amount of the vitamin to a point where the nucleic acid metabolism of the nurse cell nuclei is retarded. Such a dietary omission slows larval development and prevents adult eclosion (Sang, 1956), and dietary RNA can reverse this effect to some extent (Sang, 1959). If a similar situation holds for the adult female deprived of folic acid the ovary might then be expected to be a phenocopy of that of the sn^{36a} female. The following experiments were carried out to test this hypothesis.

Omission Experiments

Material and Methods

Hybrid *Drosophila melanogaster* larvae from reciprocal crosses between two inbred, wild type, lines (Oregon S and Crianlarich 6) were reared axenically on a synthetic medium (medium C of Sang, 1955). On eclosion, the adults of both sexes were transferred to fresh axenic medium made up with a cotton base in place of agar, and kept for 4, 8 and 16 days. Four types of media were used for adult nutrition: (1) control complete medium, or control from which (2) folic acid, (3) RNA, or (4) folic acid and RNA were omitted. When the time had come to test fecundity and fertility of flies feeding on a deficient diet in a given culture, the tube was opened and single females were sucked into flat bottomed glass vials. Each vial was inverted and stoppered with a cork covered with an agar disc. Each fly was allowed to oviposit on the discs for 24 hours at 25°C in the dark. The female was then removed, the eggs were counted and the developing embryos were given a 24 hour incubation at 25°C. Subsequently, unhatched eggs were counted. Feulgen-stained whole mounts were made of the ovaries of each female according to the procedure of King, Burnett & Staley (1957). The staining time was standardized to one hour. The whole mounts were examined microscopically at magnifications ranging from 6 to 1,400 times. The terminology (with respect to the

developmental stage of a given oocyte) used throughout this paper is that of King, Rubinson & Smith (1956).

Results and Conclusions

Table I gives the relevant results from a study of the effects upon fecundity and fertility of the omission of folic acid, RNA or both from

TABLE I

EFFECT OF NUTRITION UPON FECUNDITY AND EGG VIABILITY

The flies were grown axenically for 4, 8 or 16 days prior to testing individually the fecundity and egg mortality of *N* females. The standard error follows the ± sign.

	Eggs laid on day	*N*	Mean number of eggs per ♀	Mean egg mortality
Control medium	5	4	29.5 ± 3.4	0
Folic acid omitted	5	6	23.8 ± 5.5	0.252 ± .084
Folic acid and RNA omitted	5	4	22.0 ± 4.5	0.830 ± .053
Control medium	9	5	52.6 ± 2.5	0.015 ± .007
Folic acid omitted	9	10	17.8 ± 5.7	0.629 ± .054
Folic acid and RNA omitted	9	8	34.0 ± 5.2	0.842 ± .017
Control medium	17	11	15.2 ± 1.7	0.640 ± .058
RNA omitted	17	13	15.8 ± 3.3	0.447 ± .096

the adult diet. Fecundity rises and then falls as control females age, and egg mortality increases. Flies were transferred to fresh medium on day 8, but by this time the original males were semi-sterile and no fresh males were added. Since in another experiment the addition of young males to 11 day old females resulted in an abrupt return to normal egg viability (approximately 95%—see Fig. 1), the elevated egg mortality in the 17 day series is probably the fault of the old males. Under these experimental conditions, there is no evidence that omission of RNA for as long as 16 days has any statistically significant effect on fecundity or egg viability. Consequently, the *de novo* synthesis of RNA must be adequate when sufficient dietary folic acid is supplied. On the other hand, omission of folic acid for only 4 days increases egg mortality, and if this treatment is continued for a longer period (8 day series) it produces a decline of fecundity as well. Removal of dietary RNA along with the folic acid depresses egg viability still further but has no statistically significant effect on fecundity during the 8 day period; or, put conversely, dietary RNA reduces the effects of folic omission on egg mortality but does not influence egg production. Since purines make up about 0.4% of the laid, unfertilized *Drosophila* eggs (calculated from Levenbook, Travaglini & Schultz,

FIGURE 1

Daily, mean egg production from (A) 12 control females, (B) 16 aminopterin-fed females which resumed laying eggs, and (C) 7 aminopterin-fed females which failed to resume egg production. Viable eggs are indicated by open columns, unhatched, normal-appearing eggs by black columns and abnormal eggs (none of which hatched) by dotted columns. The females were mated prior to treatment, and fresh males were supplied to each female on the 6th day. Females were 5 days old when treated.

1958 and Travaglini, Levenbook & Schultz, 1958), one reasonable explanation of these findings is that embryogenesis cannot be completed if the purine concentration in the ooplasm falls below some critical amount. Formation of the egg is either not as sensitive to purine supply, or is affected by some other folic acid-mediated process. In either case, it is evident that the character of yolk may be modified by interference with nucleic acid metabolism.

Eight ovaries from flies fed eight days on a folic acid-free diet were examined. They were normal in morphology, but abnormal in stage distribution in that they lacked oocytes at stages 8 through 11. Since these stages are the ones during which vitellogenesis occurs, it is obvious that yolk formation is inhibited in folic acid-deficient *Drosophila* females. However, the normal appearance of the nurse cell nuclei indicates either that the original hypothesis is incorrect, that the treatment would have to be prolonged still further to prove it, or that the homeostatic mechanisms of the ovary are such that the nurse cell nuclei are protected at the expense of egg production. Table 1 sug-

gests that the last possibility is the most probable and a different approach to the problem was therefore adopted.

Experiments with Aminopterin

Inhibition of nucleic acid synthesis by folic acid antagonists such as aminopterin is well documented (Skipper, Mitchell & Bennett, 1950; Woolley, 1952). Aminopterin reacts irreversibly with the combination sites of the various folic acid-dependent enzymes and no amount of extra folic acid will dislodge it (Woolley, 1959). These facts suggested that abnormalities might be produced in the ovary by feeding adults large amounts of aminopterin for brief periods of time. Comparison of such aminopterin effects with those produced by the omission of folic acid from the diet are in any case worthwhile; so two experiments were performed. In the first experiment females (which had been reared with males on live yeast) were fed for five hours on an aminopterin: casein-peptone suspension (1:99) and control females on casein-peptone alone; after which the females were placed individually upon live yeast and their daily fecundity and fertility measured as before. Flies were sacrificed when they were either 11 or 13 days old (6 or 8 days after treatment), and their ovaries were studied cytologically. Flies were etherized only at the termination of the experiment. In the second experiment the procedure was the same except that axenic adults were used which fed for five days on axenic medium C before the five hour feeding period on aminopterin casein-peptone mixture. Ovary preparations were made on 9-day-old flies.

Results and Conclusions

Egg production records of flies from the first experiment are summarised in Fig. 1. As mentioned previously, egg mortality rises as the females age, but egg mortality falls to the original low value when young males are added, and egg production is also stimulated. The examination of egg production records of treated flies showed that there were two categories of response to aminopterin treatment: one in which the female slowed down in its egg production but then recovered and eventually laid a more or less normal number of viable eggs; and another in which egg production ceased and did not resume by the 8th day. The individual records were therefore grouped into these two experimental classes (B & C) and are compared with the control (A) in Fig. 1.

The two groups of treated females showed a decline in egg viability as early as the first day after aminopterin treatment. On the second day egg production also declined and over half the eggs laid by both groups were inviable (cf. omission experiments). Some of the eggs laid by the group which recovered were small, flaccid and either had no appendages or misshapen ones, and no eggs of this type ever hatched throughout the experiment. A normal and abnormal egg are shown in Fig. 2. The abnormal egg is 37% the volume of the normal one, has

FIGURE 2
(X52) A normal and smaller abnormal egg laid by an aminopterin-fed female.

short, blunt filaments and is reminiscent of the eggs produced by some of the sterile *singed* mutants (Mohr, 1922; King & Burnett, 1957). On the third day, the group of females which failed to recover laid only a small number of inviable, abnormal eggs and they continued to do this up to the 6th day; after which no more eggs were laid. The group which recovered laid its smallest number of eggs on the third day, and both output and viability improved thereafter; although the control values were never quite attained. Even on the 8th day some abnormal eggs were laid by this group, but as their number had declined progressively from the 4th day maximum, it is likely that production of

these abnormal eggs would have ceased eventually. No abnormal eggs were laid by the control series during the entire 8 day period.

The technique of feeding adults for a limited period is open to the objection that some flies may consume more aminopterin than others, and the variability of responses may be a consequence of this deficiency of method. If this had been so to any serious degree, the obvious division of females into two categories should not have been apparent, since the flies might be expected to give somewhat different intergrading response curves. Indeed, this is found to some extent, but the notable similarity of the two arbitrary groups during the first two days after treatment suggests that this was not the main explanation of the differences between them. So the flies were sacrificed for cytological examination (see Table II).

TABLE II
THE NUMBER OF OVARIES IN EACH EXPERIMENTAL SERIES

Group	Age (days) of females	Days after treatment	Number of ovaries observed
A	11	6	7
A	13	8	7
B	11	6	12
B	13	8	24
C	13	8	14

Ovaries from control flies had an average of 17 ovarioles each of which contained 7-8 developing oocytes. The last two egg chambers in each tube were generally at stages 10 and 14. The situation will be clarified by studying a portion of a Feulgen-stained, control ovary shown in Fig. 3. Each developing egg chamber consists of a cyst of 16 cells surrounded by an envelope of follicular cells. The most posterior of the 16 cells differentiates into the oocyte; whereas the other 15 cells become the endopolyploid nurse cells. Vitellogenesis begins at stage 8, and subsequently the oocyte increases in volume at a rate which greatly exceeds that of the nurse cells. In the stage 10 chamber shown in Fig. 3, the yolk-filled oocyte has a volume approximately equal to the combined volume of the 15 nurse cells. Ten of the nurse cell nuclei are in focus in the photomicrograph. A mature ovarian, primary oocyte (stage 14) lies behind the stage 10 chamber, but only a portion of it is included in the figure.

Ovaries of 11-day-old flies from group B are characterized by a higher frequency of oocytes in stages 8-11, which indicates that a

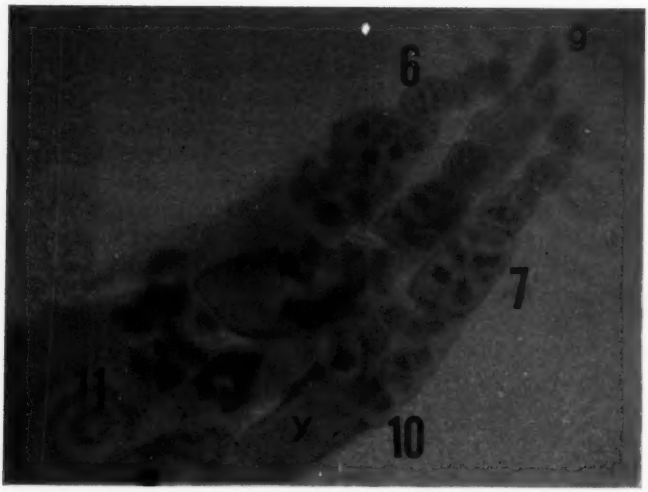

FIGURE 3

(X 134) 4 ovarioles from a Feulgen-stained control, 12 day old ovary. The numbers refer to the developmental stages attained by the adjacent chambers. e, mature egg; g, germarium, which always points anteriorly; y, yolky ooplasm. No correction is made for shrinkage during the staining procedure.

longer period of time is spent going through these stages (see King, 1957a) and therefore that there is a retardation in the rate of yolk formation. The number of stage 14 oocytes is also high which suggests that mature eggs are being stored in the ovarioles longer than normal. The chambers in an ovariole are generally pressed tightly together, and fusions of adjacent chambers are commonly found in the anterior portions of ovarioles. Such fusions are commonly noted in the ovaries of flies homozygous for various female sterile mutations and in ovaries of flies exposed to ionising radiation (see King, Burnett & Staley, 1957, p. 248; King & Burnett, 1957, Fig. 14; and King, 1957b, Fig. 6). The resemblance between the sn^{36a}, *fu* ovaries and the aminopterin-poisoned ovary is very striking (Fig. 4 should be compared with Figs. 5 and 6 in the paper of King & Burnett, 1957). In particular, the chambers in pre-yolk stages are compressed together until they are transformed from their normal ellipsoidal or spherical shape into a series of flat discs which are stacked tightly together. In other cases, the series of chambers meanders back and forth within the ovariole

with the result that adjacent chambers may lie one on top of the other instead of following one after another as in normal ovarioles. This behaviour suggests that aminopterin poisons chambers that are actively synthesising yolk and has little effect on earlier stages, with the result that chambers are continually proliferated from the germarium, develop and press into the larger, posterior, yolk-filled chambers which form a bottle-neck to further movement of chambers down the egg tube. Furthermore, adjacent chambers are often found in the same stage; something never occurring in controls, but noted in irradiated ovaries (King, 1957b). For example, developmental stages attained by adjacent chambers in the ovariole shown in Fig. 4 are 14, 14, 10, 7,

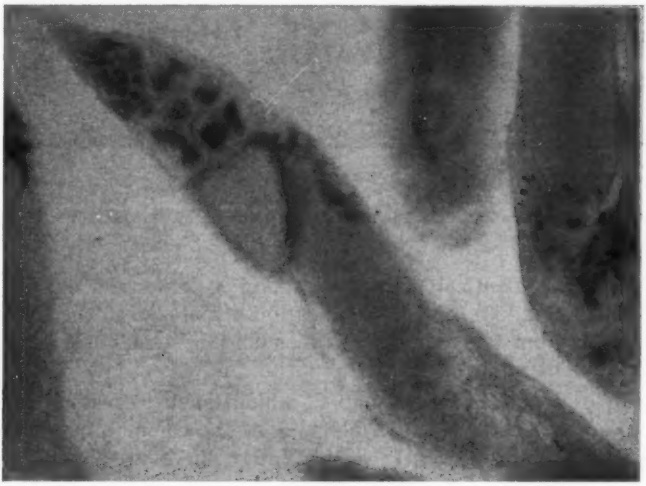

FIGURE 4

(X 134) An ovariole from a Feulgen-stained ovary of an 11 day old female of Group B showing the compressed series of developing eggs.

7, 6, 6, 3, 3 and 2. Many of the completed ovarian oocytes are abnormal (see Fig. 5), and these are often laid but never develop, as was noted earlier. The common characteristic of all abnormal eggs is their reduced volume which again points to an abnormality of yolk production during development. Some of the ovarioles of aminopterin-poisoned ovaries degenerated completely. These have not been figured,

FIGURE 5

(X 53) Mature eggs from ovarian preparations of an 11 day old female of group B photographed with dark field illumination. Compare the normal stage 14 oocytes (n) with the squat, abnormal oocytes with short filaments (a) or no filaments (b).

since they look identical with those found in irradiated ovaries (see King, 1957b, Fig. 3). The only indication of damage to the nurse cell nuclei comes from a few chambers which contain some nurse cell nuclei distinctly smaller than the rest.

The ovaries of flies from group C, which failed to resume egg production, are characterised by a blocking of the common oviducts with debris from abnormal oocytes (see Fig. 6). The ovaries contain large numbers of mature eggs which proves conclusively that oogenesis is continued in these sterile flies. This fact demonstrates how misleading egg production records may be if not complemented by cytological studies (see Mitlin, Butt and Shortino, 1957). The stage distribution in such blocked ovaries is quite abnormal. The developmental stages attained by adjacent oocytes are generally, 1, 4, 5, 6, 7, 14, 14, 14. Since the number of oocytes per tube (8) is not unusually large, it follows that proliferation of further chambers has ceased in blocked ovaries containing mature eggs, and this may indicate that some control mechanism operates in *Drosophila* which causes a cessation of pro-

FIGURE 6

(X 20) The living reproductive system of a group C female. The common oviduct is blocked at *x*.

duction of further egg chambers by the germarium, once the ovarioles are packed with mature eggs.

Ovaries from aminopterin-poisoned females which resumed egg production were generally normal. Ovaries from females laying a reduced number of eggs were often larger, containing more stage 14 oocytes and fewer oocytes in stages 8-11 than those from controls. In some cases the two ovaries from a fly characterised by lowered fecundity differed in size; one being normal in morphology and size, the other larger. The larger ovary in such cases evidently had failed to discharge its abnormal eggs for these partially blocked the calyx.

In experiment 2, aminopterin was fed to axenic flies grown on synthetic medium C; whereas flies were pre-fed yeast in the first experiment. King & Wilson (1955) showed that a *Drosophila melanogaster* female ingests daily an amount of yeast roughly equal to its body weight. Under such circumstances the fly would ingest about 0.25 micrograms of thymidine and 18 micrograms of RNA. A fly ingesting an equal quantity of medium C would obtain 60 micrograms of RNA and no thymidine. Therefore the level of thymidine in the tissues might be expected to be considerably higher in the flies of experiment 1 when

fed aminopterin than in those of experiment 2. Since aminopterin-poisoning should reduce the ability of the fly to synthesize thymidine, the effect of the drug on the ovary should be more drastic in the second experiment. Such proved to be the case.

In this experiment the treated series contained 5 females; the control 7. Both control and treated females laid approximately 50 eggs on the first day after treatment. During the subsequent two days the controls continued to produce 50 eggs daily; whereas the fecundity of treated flies dropped to zero. The ovaries of control and treated flies were removed and studied on the 4th day after treatment.

The ovarioles from females which became sterile following the aminopterin meal contained an average of 7 chambers none of which was more advanced than stage 8. Since the average number of eggs laid by poisoned flies was known as well as the stage distribution of ovarian oocytes prior to the aminopterin meal, it can be calculated that all stage 12-14 oocytes (which at the time of treatment had finished forming their yolk) were laid, and that stage 10-11 oocytes (which had completed DNA synthesis in nurse cell nuclei and had laid down at least half of their yolk) completed development and were also laid. Vitellogenesis was thus blocked in the less mature oocytes of the aminopterin-poisoned ovary of the flies in experiment 2.

Correlated with this phenomenon is a reduction in the amount of Feulgen-positive material in the nurse cells. The oocyte and follicle cells seem normal, but the nurse cells in any chamber respond to the inhibitory effects of aminopterin in a polarised fashion. In Fig. 7, ovarioles from treated flies are shown which contain large numbers of stage 6 chambers. These chambers were probably at stage 4 when the aminopterin entered. In each chamber three or four anterior, nurse cell nuclei of about the same size are Feulgen-positive, whereas the rest are heterogeneous in size and contain little or no DNA. The Feulgen-positive nuclei are also abnormal since the chromosomes they contain are more similar morphologically to those of a stage 4 nurse cell nucleus. However, the chromosomes seem more despiralised, and in this respect they resemble the nurse cell chromosomes seen in the ovaries of flies homozygous for the female sterile gene *fs 2.1* (King & Burnett, 1957). Since it is known from the work of Jacob & Sirlin (1959) that the stage 6 nurse nucleus contains twice as much DNA as the stage 4 nucleus, it is probable that the Feulgen-positive nuclei of aminopterin-poisoned, stage 6 nurse cells contain less than the normal

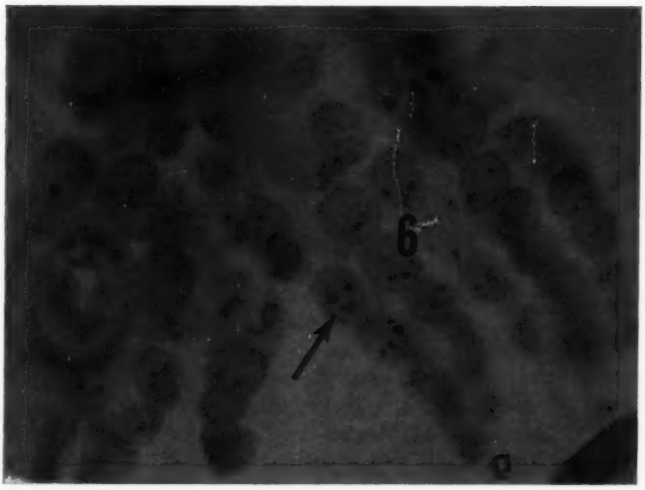

FIGURE 7

(X 134) 10 ovarioles from an aminopterin-poisoned ovary from the second experiment. Note that most chambers are at stage 6 and that no yolky stages (stages 10 and 11) are present. Stage 6 chambers (such as the one marked by the arrow) contain only a few anterior, Feulgen-positive, nurse cell nuclei.

amount of DNA. We conclude that aminopterin stopped DNA synthesis in stage 4, but the chambers increased in size to stage 6, and the nurse cell chromosomes elongated in the normal fashion.

Those treated chambers which reached stage 8 and laid down some yolk generally have 4-6 Feulgen-positive nurse cell nuclei; whereas stage 6 chambers have only 3 or 4 such nuclei. Fusions of adjacent chambers in the anterior portion of the ovariole are again common.

Discussion

The hypothesis on which this study was based was that interference with folic acid metabolism would indirectly modify the synthesis of nucleic acids in the active ovary of the adult *Drosophila*, and so produce changes in its structure copying those found in the female sterile mutation sn^{36a}. The results reported above are in agreement with this hypothesis and show that phenotypes similar to sn^{36a} and *fs 2.1* result from the treatment. Some deficiency of the nucleic acids of the nurse cell nuclei of all of those mutants appears to cause the production of

defective yolk, or of inadequate amounts of yolk (King & Burnett, 1957) and the formation of an abnormal ovum. Experimental manipulation of folic acid dependent systems produces a like spectrum of effects, and also a wider range of changes than has so far been described for this class of female sterile mutations. Taken together, these two groups of facts reinforce the conclusion that nucleic acids play a key role in yolk synthesis.

Direct removal of dietary RNA affects egg viability very little unless it is accompanied by a simultaneous withdrawal of folic acid (Table I). The *de novo* synthesis of RNA by adults must generally be adequate for normal egg production when dietary folic acid is provided. If folic acid is not supplied, egg production is slowed down even when RNA is fed, suggesting that there is a distinction between the folic acid mediated processes which are involved in the growth of the ovum and in the production of a viable ovum; the latter being more RNA dependent. Only folic acid deficiency appears to affect the normal course of egg production, and it does this by inhibiting vitellogenesis but without causing cytological abnormalities detectable by the methods used. Deficiencies of other vitamins have a similar effect (Sang and King, unpublished) and also produce a regulated but slowly developing ovary, so this process must be controlled by many mechanisms. The more drastic treatment of exposure to a folic acid analogue which acts irreversibly is alone capable of demonstrating the effects of folic acid deficiency against the regulative processes which underly ovary growth. That these processes extend to a control over cell division in the germarium itself is shown by the limited growth of the ovary when the oviduct is blocked.

The ability of the ovary to recover from aminopterin treatment has been reported by Goldsmith and Frank (1952), who also noted that some females never laid eggs after treatment, presumably due to blocking of the oviduct as in the aminopterin experiment described above. No significant cytological changes were observed in our first aminopterin experiment, probably because recovery was nearly complete by the time the ovaries were removed for examination. Certainly, such changes must have occurred earlier since abnormal eggs were laid. But it is only in the second aminopterin experiment that cytological abnormalities are clearly discernible, and some of these deserve comment.

The most significant cytological abnormality is the polarised re-

sponse of nurse cells to aminopterin (Fig. 7), and it is very difficult to explain. It is unlikely that this is due to a polarised, morphological barrier which prevents aminopterin from entering the anterior cells of the 16-cell cyst, since the cuboidal epithelium surrounding it is of the same thickness at all regions, and normal cysts have nurse cells of the same size with nuclei which are indistinguishable one from the other (King, Rubinson and Smith, 1956). Furthermore, when flies are fed tritiated uridine or glycine for an hour, tritium appears in similar quantities in the nucleoplasm and cytoplasm of all the nurse cells in a cyst (King and Burnett, 1959).

On the other hand, the cyst shows a fundamental polarisation from the beginning, since the oocyte is always the most posterior of the 16 daughter cells in a chamber. The nuclei of nurse cells nearest to the oocyte appear to be more advanced morphologically as early as stage 5, and they are the largest nuclei during stages 7-10 (King, Rubinson & Smith, 1956) as can be seen in Fig. 3. According to Jacob and Sirlin (1959), the DNA of these posterior nurse cell nuclei undergoes one replication more than the anterior nuclei during stages 7-10. When the maximum DNA values are reached in stage 10 the posterior nuclei reach this concentration first and then lose DNA. Conversely, the anterior nuclei show no loss of DNA (Jacob and Sirlin, loc. cit.). When the vitelline membrane surrounds the oocyte, Feulgen-positive nurse cell nuclei remain behind (see Fig. 26 of King, Rubinson & Smith, 1956) and only breakdown products of DNA could enter the oocyte and these would originate mainly from adjacent, posterior nurse cells and represent only a small portion of the total DNA of all nurse cell nuclei. Consequently, a polarisation of function of nurse cells must be postulated which becomes apparent cytologically from about stage 7, as a polarisation of nuclei, when yolk starts to be laid down.

The significant difference between nuclei of the anterior and posterior nurse cells of a cyst is not only their content of DNA but also the capacity of posterior nuclei to break down to Feulgen-negative units. When DNA replication in nurse cell nuclei is inhibited by aminopterin, and yolk formation stopped, it becomes apparent that this breakdown of DNA can occur at all stages of cyst development and among all nurse cell nuclei, since some cysts are completely Feulgen-negative. This last situation is not the commonest (Fig. 7), and the distinction between anterior and posterior nuclei with respect to DNA breakdown can be seen in many younger chambers. The polar-

isation of the cells of a cyst is therefore exposed by aminopterin treatment and is found to extend to all of them and to be present from the earliest stages at which cytological observation is possible.

It does not follow that aminopterin has any direct effect on the process which leads to DNA breakdown (indeed, the contrary would seem to be indicated), but as so little is yet known about the metabolism of the ovary there is little point in speculating about this. What is clear is that the striking similarities between the cytology of ovaries treated with aminopterin and of those from such female sterile mutations as sn^{36a} and *fs 2.1* suggest that the same mechanisms may be involved, and that study of the folic acid metabolism of these mutants would offer a supplementary approach to the problems noted here.

Summary

The effects on fecundity and fertility of omission of folic acid, with and without RNA, from the diet of axenically cultured *Drosophila melanogaster* are described and correlated with the changes which these treatments produce in the ovary. No cytological abnormalities are caused, but there is a slowing down of yolk production, and therefore of egg formation, and a considerable proportion of the eggs laid are inviable. The more drastic treatment of feeding aminopterin for a 5 hour period to adult females results in the formation of inviable, abnormal eggs and in the cessation of egg production. Recovery is possible and occurs in most cases, although some females fail to lay the eggs they form due to a blockage of the oviducts by abnormal eggs. Ovaries of aminopterin-treated flies also have a deficiency of yolky stages and the nurse cell nuclei show a notable polarity in their staining properties. Ovaries of treated females are similar in structure to those of the female sterile mutations sn^{36a} and *fs 2.1*, and it is suggested that the yolk deficiencies which characterise these mutations are a consequence of a defective nucleic acid metabolism and that normal yolk production depends on the development of nurse cell nuclei following its proper course. Aminopterin treatment exposes an underlying polarity among these nuclei which seems to be determined at the earliest stages.

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BODY SIZE AND FORM OF AMERICAN-BORN BOYS OF DUTCH ANCESTRY RESIDING IN MICHIGAN

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(Received April 20, 1959.)

THIS study pertains focally to the growth[1] of North American schoolboys of Dutch ancestry. The boys were drawn from the schools at Holland, Michigan, during the 1957-58 academic year. Three samples were taken, one each at ages 7 years, 11 years, and 15 years.

Viewed broadly, the study makes several contributions to a developing pattern of research on body size and form[2] during childhood and adolescence. In doing this, it extends knowledge on the following topics: variations in average size of North American children of different ethnic subgroups (6, 10, 15, 21); secular, or generational, change in body size (7, 8, 9, 18); inter-age trend, and intra-age variability, in body form (3, 16, 17, 19); and association among components of body form (5, 14, 20, 26).

PURPOSE

Major aims of the investigation are:

1. To describe present day American-born schoolboys of Dutch ancestry with respect to 7 measures of body size. These measures are stature, stem length, lower limb length, thorax girth, abdomen girth, leg girth, and body weight.

2. To describe present day American-born schoolboys of Dutch ancestry with respect to 4 measures of body form. Two of these measures represent "slender-to-stocky" continua: leg girth x 100/lower limb length, and thorax girth x 100/stem length. The other 2 depict "regional predominance" continua: thorax girth x 100/abdomen girth, and lower limb length x 100/stem length.

[1] The term "growth" is used with the connotation recognized in the founding of this journal (2). It encompasses changes during ontogenesis in the size, form, number, kind, location, and composition of an organisms's anatomic constituents (12).

[2] Various investigators make synonymous use of the terms form, shape, build, physique, constitution, somatotype, and body proportions (26).

3. To compare age-matched means for stature and body weight from 2 series of North American schoolboys of Dutch ancestry separated in time by a quarter of a century. In attaining this objective, findings from our 1957-58 data are aligned with findings from data collected 1931-33 in the same schools (25).

4. To compare the body size and form of different ethnic subgroups of present day North American schoolboys. Intercomparisons are made for American-Dutch boys residing in Michigan (present study), American-Japanese boys residing in California (1), and American-North European boys residing in Oregon (11, 22, 26).

SUBJECTS

The original subjects were 246 boys enrolled 1957-58 in schools at Holland, Michigan; 152 attended the public schools, and 94 the Christian schools;[3] 73 represented age 7 years, 77 age 11 years, and 96 age 15 years.

To be accepted, a boy had to meet the following criteria: (1) born in North America, (2) at least 3 grandparents of Dutch lineage, and (3) within 2 months of one of the ages (birth anniversaries) selected for study.

The school superintendents made available lists of all the white boys who satisfied one of the age specifications sometime during the 1957-58 academic year. Each boy on these lists was investigated with respect to birthplace and descent. In the Christian schools the homeroom teacher telephoned the homes to obtain this information. In the public schools a questionnaire requesting the information was sent to each home.

The family of every boy who satisfied the three criteria was telephoned or visited by J.H.S. The purposes of this contact were to explain the objectives and scope of the study, request cooperation, and schedule a date for the boys' examination. Full cooperation was secured from more than 95 per cent of the families.

Subjects were scheduled for measurement between 4:00 P.M. and 9:00 P.M.; J.H.S. went to the home of each subject in his automobile, drove the subject to an anthropometric laboratory, conducted the examination, and provided transportation for the return trip.

[3] Acknowledgment is made to Superintendent Bert Bos and the cooperating staff of the Holland Christian schools, also to Superintendent Walter W. Scott and the cooperating staff of the Holland Public Schools.

Measurement Procedures

The boys were measured in a well lighted and comfortably heated room. At the time of measurement they wore gym shorts only. One anthropometrist (J.H.S.) made all the measurements. He had received training under H.V.M., and was assisted regularly by his wife. On two occasions a few months apart, H.V.M. visited the laboratory to check on the maintenance of anthropometric technique.

Detailed specification of the procedures used in obtaining the different measurements is available in an earlier issue of this journal (11). Consequently, it will suffice here to present succinct identifications:

Stature (*vertex-soles distance*). Erect body height taken with the subject's heels, buttocks, and upper part of back in contact with an upright board to which a millimeter scale was attached.

Stem length (*vertex-infraischia distance*). Maximum rectilinear distance from the vertex to the upper surface of a standard bench. The subject was oriented in an erect sitting position with his buttocks and upper back contacting the anthropometric board.

Lower limb length (*infraischia-soles distance*). Stature minus stem length, *i.e.*, maximum vertical distance from the most inferior level of the ischia to the plantar surface of the heels.

Thorax girth (*xiphisternal level*). Circumference of the trunk, at the level of the xiphisternal junction, under conditions of normal respiration.

Abdomen girth (*umbilical level*). Circumference of the trunk, during normal erect posture, at the level of the umbilicus. In instances of umbilical protrusion, the measurement was taken immediately superior to the umbilicus.

Leg girth (*calf level*). Maximum horizontal circumference of the left leg in the region of the calf.

Body weight (*unclothed*). Weight with the subject standing in the middle of the platform on beam-type scales, wearing nothing except gym shorts.

Two subjects were involved in each measuring session. A complete set of measurements was taken first on the one subject, then on the other. The same procedure was repeated until each subject had been measured 4 times. When the 4 records for a given dimension were in close agreement, they were averaged. "Close agreement" required that

the different records on a boy agree within 0.2 kg. for body weight, 0.2 cm. for leg girth, 0.5 cm. for stature, and 1.0 cm. for the other dimensions. When a record differed from the other 3 by more than the amount allowed, the mean of the homogeneous triad was used.

Findings on Body Size

Descriptive findings. Table I presents central tendency and variability statistics at 3 postnatal ages for 7 measures of body size. If

TABLE I

Central Tendency and Variability Statistics for 7 Measures of Body Size on Michigan Schoolboys of Dutch Descent Studied 1957-58

Measurement	Mean	Standard Deviation	Minimum	Percentiles 10	30	70	90	Maximum
			7 Years: N = 77					
Stature (cm.)*	122.4	4.99	110.7	116.4	119.7	125.2	128.1	135.3
Stem length	66.8	2.95	60.7	63.2	65.3	67.9	70.8	74.1
Lower limb length	55.6	2.66	49.9	52.2	54.0	57.2	58.8	62.0
Thorax girth	60.4	3.22	52.5	57.0	58.7	61.6	64.3	71.8
Abdomen girth	56.8	4.46	47.3	52.1	54.7	58.3	61.9	74.2
Leg girth	25.0	1.80	21.1	22.9	24.1	25.7	27.6	31.4
Body weight (kg.)	24.6	3.90	17.2	20.5	22.4	26.0	28.9	39.7
			11 Years: N = 73					
Stature (cm.)*	146.4	6.00	131.6	139.2	142.3	149.7	154.2	162.5
Stem length	76.7	2.84	71.3	72.9	74.9	78.1	80.3	85.4
Lower limb length	69.7	3.85	58.9	64.8	68.0	71.8	75.2	77.1
Thorax girth	70.0	5.02	61.5	64.6	68.9	71.7	73.9	89.8
Abdomen girth	66.1	6.54	56.2	60.4	62.7	67.0	73.1	88.4
Leg girth	29.7	2.35	25.8	26.8	28.6	30.7	32.9	36.0
Body weight (kg.)	39.0	6.44	29.5	31.8	35.0	41.5	46.3	61.7
			15 Years: N = 96					
Stature (cm.)*	171.6	8.01	149.8	160.8	168.0	175.6	181.7	192.8
Stem length	87.9	4.90	73.6	81.0	86.1	90.3	93.7	101.3
Lower limb length	83.7	4.37	73.8	77.3	81.7	86.4	89.7	92.5
Thorax girth	83.1	6.00	72.1	76.7	79.6	85.4	91.5	109.9
Abdomen girth	75.1	6.76	61.8	68.2	71.0	77.8	84.2	105.3
Leg girth	35.0	2.87	23.2	31.8	33.8	36.3	38.6	45.0
Body weight (kg.)	61.2	9.47	40.9	49.6	55.7	65.5	75.2	83.7

* The values for this and the following 5 measurements are in centimeters.

each trait were distributed as a normal frequency surface, it would be redundant to supplement the method of variability analysis represented in column 2 with that represented in columns 3 to 8. Actually, the distributions are approximately normal for the vertical dimensions, and positively skewed for body weight and the transverse dimensions (4).

It would be tedious to attempt enumeration of all the findings contained in Table I. A more useful explication is obtained by listing and illustrating different types of information that the reader may draw from the table:

1. *Average size at each of the ages studied.* At age 7 years, the mean obtained for stem length on schoolboys of Dutch descent residing 1957-58 at Holland, Michigan, is 66.8 cm. On the assumption of random sampling, it is estimated at the 1 per cent confidence level that the population mean for this trait lies between 65.9 cm. and 67.7 cm.[4]

2. *Comparative average size of different dimensions.* For the sample of American-Dutch schoolboys drawn to represent age 11 years, mean abdomen girth is (a) smaller than mean thorax girth by 3.9 cm., or 5.6 per cent, and (b) larger than mean calf girth by 36.4 cm., or 122.5 per cent.

3. *Change in average size during quadrennial and octennial intervals.* Reference to the central tendency statistics for body weight shows that there are increases of (a) 14.4 kg., or 58.5 per cent, between ages 7 and 11 years, (b) 22.2 kg., or 56.9 per cent, between ages 11 and 15 years, and (c) 36.6 kg., or 148.8 per cent, between ages 7 and 15 years.

4. *Variability at each of the ages studied.* In stature, 30 per cent of the boys age 15 years are shorter than 168.0 cm. and another 30 per cent taller than 175.6 cm. The percentiles for body weight at this age indicate that one-tenth of the boys are lighter than 49.6 kg. and one-tenth heavier than 75.2 kg.

5. *Comparative variability of different traits.* At all 3 ages, the standard deviation for abdomen girth is larger than that for thorax girth. Comparisons by use of the coefficient of variation (standard deviation x 100/mean) indicate that variability is less than 5.0 per cent for stature and more than 15.0 per cent for body weight.

6. *Overlap of trait distributions for different ages.* The 3 distributions for lower limb length show the least overlap. Taking as a reference value the maximum at age 7 years (62.0 cm.), fewer than 10 per cent of the boys age 11 years have lower limbs that are shorter than this, whereas none of the boys age 15 years have lower limbs shorter than 73.0 cm. Greatest overlap occurs for abdomen girth: the

[4] Obtained mean $\pm$ $(4.99/\sqrt{77-1}) \times 2.58$.

90th percentile at age 7 years, 20th percentile at age 11 years, and the minimum value at age 15 years each approximate 62.0 cm.

To this point, the original data for body size have been described by means of central tendency and variability statistics. They may be analyzed further by means of correlation statistics. Table II exhibits

TABLE II
CORRELATION STATISTICS (r) OBTAINED FROM DATA FOR BODY SIZE ON 73 AMERICAN-DUTCH SCHOOLBOYS 11 YEARS OF AGE

Measurement	Stem Length	Thorax Girth	Abdomen Girth	Leg Girth	Body Weight
Lower limb length	0.53	0.28	0.20	0.43	0.46
Stem length		0.55	0.49	0.59	0.70
Thorax girth			0.90	0.85	0.92
Abdomen girth				0.84	0.91
Leg girth					0.94

15 coefficients symbolizing concomitant variation of pairs of traits on the 73 boys 11 years of age. Findings are:

1. The association between the 2 trunk girths ($r = 0.90$) is considerably higher than that between the 2 components of stature ($r = 0.53$).

2. Leg girth is associated more strongly with the trunk girths (r's ca. 0.85) than with lower limb length ($r = 0.43$).

3. Coefficients between 0.40 and 0.60 are obtained for stem length with each of the 3 girths, and for lower limb length with stem length, leg girth and body weight.

4. Coefficients between 0.90 and 0.95 are obtained for body weight with the trunk and limb girths. On a sample of 6,500 boys 11 years of age, O'Brien, Gershick and Hunt (23) secured a correlation coefficient of $r = 0.76$ for body weight with stature.

5. The coefficient for lower limb length with abdomen girth ($r = 0.20$, df 71) is not significantly different from zero. At the 5 per cent level of statistical significance, the coefficient for lower limb length with thorax girth allows rejection of the hypothesis that the population r is zero.

Comparative findings. A quarter of a century earlier than the time the data for the present study were gathered, Steggerda and Densen (25) amassed data for stature and body weight on boys of Dutch descent enrolled "in the schools of Holland, Michigan." The 2 collections represent the temporal periods 1931-33 and 1957-58. Steggerda

and Densen state that their 1931-33 sample consists of boys "whose ancestors came from the Netherlands"; 60 per cent of the boys in our 1957-58 sample had 4 grandparents of Dutch ancestry and 40 per cent 3 grandparents of Dutch ancestry. Means from the two studies are juxtaposed in Table III. It is found:

1. For stature at 2 ages, and for body weight at all 3 ages, dif-

TABLE III
MEANS FOR TWO SECULAR PERIODS ON MICHIGAN SCHOOLBOYS OF DUTCH ANCESTRY

Age (yrs.)	1931-33*	1957-58**	1957-58 minus 1931-33
	Stature		
7	123.3	122.4	—0.9
11	144.3	146.4	2.1
15	168.6	171.6	3.0
	Body Weight		
7	22.9	24.6	1.7
11	33.8	39.0	5.2
15	50.5	61.2	10.7

* N's are 220, 189 and 149 at ages 7, 11 and 15 years, respectively.
** N's are 77, 73 and 96 at ages 7, 11 and 15 years, respectively.

ferences between means for the 2 secular periods are statistically significant at the 1 per cent level of confidence. The hypothesis that the stature means at age 7 years represent random samples from a common population cannot be rejected.[5]

2. The obtained means for body weight show present day American-Dutch boys to be heavier than American-Dutch boys a generation ago by 1.7 kg. at age 7 years, 5.2 kg. at age 11 years and 10.7 kg. at age 15 years. A similar progressive difference during childhood and early adolescence has been found in other studies of secular variation (13).

3. Divergence of the age trends for mean stature harmonizes with that for body weight, and for stature in other comparisons (13). On American-Dutch boys age 15 years, the mean obtained from the 1931-33 data is lower than that from the 1957-58 data by 3.0 cm.

During the present decade measurements of body size have been accumulated on American-born boys of Japanese ancestry and American-born boys of northwest European ancestry. The American-Japanese boys were residing in the San Francisco Bay area of California;

[5] Comment on this is postponed pending presentation of other comparative findings (see footnote 6).

they were measured 1956-57 by Greulich (1). The American-North European boys lived at Eugene, Oregon; they were examined in 1950 by Meredith (11) and Newcomer and Meredith (22). Included in the Greulich study are means for stature, stem length, and body weight at each of the 3 ages under consideration; the other 2 studies supply means at ages 7 years and 15 years, respectively, for all 7 of the measurements being investigated.

Contemporary Michigan boys of Dutch descent are aligned in Table IV with Oregon boys of northwest European descent, and in Table V

TABLE IV
MEANS FOR TWO ETHNIC SUBGROUPS OF NORTH AMERICAN SCHOOLBOYS STUDIED 1950-58

Measurement	Dutch Lineage*	Northwest European Lineage**	Dutch minus Northwest European
	Age 7 years		
Stature (cm).	122.4	123.2	—0.8
Stem length	66.8	67.9	—1.1
Lower limb length	55.6	55.3	0.3
Thorax girth	60.4	58.3	2.1
Abdomen girth	56.8	56.3	0.5
Leg girth	25.0	24.8	0.2
Body weight (kg.)	24.6	24.2	0.4
	Age 15 years		
Stature (cm.)	171.6	169.3	2.3
Stem length	87.9	87.6	0.3
Lower limb length	83.7	81.6	2.1
Thorax girth	83.1	79.9	3.2
Abdomen girth	75.1	75.9	—0.8
Leg girth	35.0	34.9	0.1
Body weight (kg.)	61.2	60.1	1.1

* Data collected in Michigan; N's 77 at age 7 years and 96 at age 15 years.
** Data collected in Oregon; N's 136 at age 7 years and 102 at age 15 years.

with California boys of Japanese descent. In relation to the 1957-58 means on American-Dutch boys, the 1950 means on the ethnically less homogeneous white sample are:

1. Similar for abdomen girth, leg girth, and body weight. At neither age is there a statistically significant difference in any of these traits.

2. Smaller for thorax girth. At each age, a population difference in this dimension is tenable at the 1 per cent level of confidence.

3. Smaller at age 15 years in stature and lower limb length. Sig-

TABLE V
MEANS FOR TWO ETHNIC SUBGROUPS OF NORTH AMERICAN SCHOOLBOYS STUDIED 1956-58

Age (yrs.)	Dutch Lineage*	Japanese Lineage**	Dutch minus Japanese
	Stature (cm.)		
7	122.4	117.8	4.6
11	146.4	140 2	6.2
15	171.6	164.5	7.1
	Stem length (cm.)		
7	66.8	66.2	0.6
11	76.7	76.1	0.6
15	87.9	88.5	—0.6
	Body weight (kg.)		
7	24.6	23.7***	0.9+
11	39.0	36.4	2.6+
15	61.2	57.7	3.5+

* Data collected in Michigan; N's 77, 73, and 96 at ages 7, 11 and 15 years, respectively.

** Data collected in California; N's 52, 36 and 31 at ages 7, 11 and 15 years, respectively.

*** The American-Japanese boys were weighed in their indoor clothing, except for removal of "shoes and jackets or sweaters."

nificance tests allow rejection of the null hypothesis at the 1 per cent level for lower limb length, and at the 5 per cent level for stature.[6]

Turning from Table IV to Table V, it is seen:

1. At age 11 years, the average stature of American-Dutch boys exceeds that of American-Japanese boys by approximately 6.0 cm. For the octennium between ages 7 years and 15 years, there is an increasing difference in stature with age.

2. During childhood and early adolescence, the average stem length of North American boys of Japanese lineage is practically the same as that for North American boys of Dutch lineage.

3. North American boys of Dutch lineage are heavier than North American boys of Japanese lineage, the magnitude of the discrepancy becoming greater with age. On adjusting for clothing by subtracting as little as 0.5 kg. from the American-Japanese means, the obtained differences in mean weight are 1.4 kg. at age 7 years, 3.1 kg. at age 11 years, and 4.1 kg. at age 15 years.

[6] It will be noted that at age 7 years the mean for stature from the 1957-58 American-Dutch sample appears low in Table IV, as it did in Table III. Probably this mean is an atypical statistic that seriously underestimates the parameter of the population.

Findings on Body Form

As indicated earlier, data for 4 measures of body form were derived. Two of these measures quantify the stockiness, or slenderness, of the body stem and lower limbs. The other 2 quantify the predominance of upper trunk to lower trunk, and lower limbs to body stem.

Descriptive findings. Assembled in Table VI are the results from

TABLE VI

Central Tendency and Variability Values for 4 Measures of Body Form on Michigan Schoolboys of Dutch Ancestry Studied 1957-58

Measurement	Mean	Standard Deviation	Minimum	Percentiles 10	30	70	90	Maximum
			7 Years: N = 77					
Stem index	90.4	4.20	84.1	85.7	87.7	91.8	96.5	109.4
Lower limb index	45.0	2.52	39.6	41.9	43.6	46.0	48.3	53.4
Trunk index	105.5	4.45	94.3	100.9	104.6	108.2	111.6	119.1
Skelic index	83.3	3.55	73.4	79.4	81.4	84.8	88.1	94.4
			11 Years: N = 73					
Stem index	91.3	5.49	82.7	85.6	88.2	92.0	95.9	112.4
Lower limb index	42.7	3.22	35.9	39.3	41.0	43.7	45.9	53.4
Trunk index	105.2	4.42	94.8	99.8	104.4	109.1	111.7	114.0
Skelic index	91.0	4.06	81.0	85.6	88.6	93.5	96.2	98.1
			15 Years: N = 96					
Stem index	94.7	6.50	81.8	88.4	91.2	96.2	102.4	115.6
Lower limb index	41.8	3.34	30.8	38.1	40.0	43.5	46.3	50.9
Trunk index	110.9	5.27	98.0	104.4	108.0	113.5	117.5	128.5
Skelic index	95.3	4.77	80.9	89.4	92.9	97.8	101.4	107.6

central tendency and variability analyses of age-specific data on each of the 4 traits. For succinct identification, the traits are listed as stem index (thorax girth x 100/stem length), lower limb index (leg girth x 100/lower limb length), trunk index (thorax girth x 100/abdomen girth), and skelic index (lower limb length x 100/stem length). Findings from Table VI on central tendency are:

1. Over the period from 7 years to 15 years, the body stem becomes stockier with age. Thorax girth expressed in percentage of stem length rises from 90.4 at 7 years, through 91.3 at 11 years, to 94.7 at 15 years. On the assumption of random sampling, the population means at the 2 terminal ages may be regarded with high confidence as dependably different ($t = 5.2$).

2. During childhood and early adolescence the lower limbs become more slender with age. Calf girth in percentage of lower limb length shows a decline from 45.0 at age 7 years to 41.8 at age 15 years. This

difference of 3.2 in mean lower limb index is statistically significant ($t = 7.2$).

3. Circumference of the upper trunk is less predominant with respect to circumference of the lower trunk at ages 7 years and 10 years than at age 15 years. Thorax girth approximates 106 per cent of abdomen girth at the 2 childhood ages, and 111 per cent of abdomen girth at age 15 years. There is substantial statistical basis ($t = 6.3$) for inferring that during early adolescence the thoracic region of the trunk enlarges in perimeter relative to the abdominal region.

4. Marked increase with age occurs in predominance of the lower limb segment of stature with respect to the body stem segment. Ascent of the skelic index mean values is from approximately 83 per cent at 7 years, through 91 per cent at 11 years, to 95 per cent at 15 years. The difference between any two of these means is significant statistically at the 1 per cent confidence level.

Selected findings on variability from Table VI are:

1. Forty per cent of the stem indices cluster between 87.7 and 91.8 at age 7 years, 88.2 and 92.0 at age 11 years, 91.2 and 96.2 at age 15 years. For 10 per cent of the boys age 11 years, thorax girth is less than 85.6 per cent of stem length. Another 10 per cent of the boys this age have indices of stem stockiness above 95.9.

2. The stem index is more variable than the skelic index. This is seen most readily at ages 11 years and 15 years; at each of these ages, note the similarity of the index means and the difference between the standard deviations.

3. For no less than 90 per cent of the boys at all 3 ages, thorax girth equals or exceeds abdomen girth. Trunk indices above 108 per cent are found for 30 per cent of the boys age 7 years, and 70 per cent of those age 15 years. Ten per cent of the indices representing 7 years are above 111, and 10 per cent of those representing 15 years above 117.

4. At age 7 years, the minimum value of the distribution for the lower limb index approximates 40 per cent. At age 15 years, 30 per cent of the boys have calf circumferences that are less than 40 per cent of lower limb length.

The Pearson product-moment r was used to study concomitant variation of (1) stem index and lower limb index, (2) lower limb index and trunk index, and (3) trunk index and skelic index. For none of these pairings does a dimension employed in deriving the x-variate

enter into computation of the y-variate, *e.g.*, in (1) the ratio of thorax girth to stem length and the ratio of leg girth to lower limb length are correlated.

Associations were investigated at age 11 years (N = 73). Inspection of the 3 bivariate entry diagrams showed the rectilinearity and homoscedasticity assumptions for utilization of the r formula to be approximated satisfactorily. Findings are:

1. There is a moderate positive association between stockiness of the body stem and stockiness of the lower limbs. The obtained correlation for stem index and lower limb index is $r = 0.69$.

2. A moderate negative association exists between stockiness of the lower limbs and predominance of thorax girth over abdomen girth. The sample coefficient for lower limb index and trunk index is $r = -0.44$.

3. The relationship between the trunk and skelic indices is near zero, indicating practically independent variation. Statistically, on the basis of $r = 0.10$ (df 71), the hypothesis that the population r is zero cannot be rejected.

Synthesizing, stocky lower limbs show moderate direct relation with stocky stem and prominent abdomen, while prominent thorax shows moderate direct relation with slender lower limbs and practically no relation with predominance of the infraischial component of stature.

Comparative findings. Body form comparisons will be made with respect to (1) absolute magnitude of index means, (2) trend of index means on age, and (3) correlation of indices.

Table VII juxtaposes index means from the present study on North American schoolboys of Dutch ancestry and from 3 studies on North American schoolboys of northwest European ancestry (11, 17, 26). The latter supply analyses of 1929-36 data for the skelic index at ages 7 years and 15 years (17), and of 1950 data for the stem, lower limb and trunk indices at ages 7 years (11) and 15 years (26). In each instance these materials are methodologically comparable with our 1957-58 materials. Findings from Table VII are:

1. In relation to present day American-North European schoolboys, present day American-Dutch schoolboys have higher stem and trunk indices. These higher index means imply a larger thorax girth relative to both stem length and abdomen girth. Each difference (see rows

TABLE VII
MEANS FOR 4 MEASURES OF BODY FORM ON AMERICAN-BORN WHITE SCHOOLBOYS STUDIED 1929-1958

Measure	American-Dutch 1957-58*	American-North European 1950**	American-North European 1929-36***	Dutch minus North European
		Age 7 years		
Stem index	90.4	86.1		4.3
Lower limb index	45.0	44.9		0.1
Trunk index	106.5	103.8		2.7
Skelic index	83.3		82.9	0.4
		Age 15 years		
Stem index	94.7	91.1		3.6
Lower limb index	41.8	42.8		—1.0
Trunk index	110.9	105.6		5.3
Skelic index	95.3		93.9	1.4

* Data collected in Michigan; N's 77 at age 7 years and 96 at age 15 years.
** Data collected in Oregon; N's 136 at age 7 years and 107 at age 15 years.
*** Data collected in Iowa; N's 207 at age 7 years and 211 at age 15 years.

1, 3, 5 and 7 of Table VII) is statistically significant at the 1 per cent confidence level.

2. With respect to lower limb index, North American schoolboys of Dutch lineage do not differ significantly from North American schoolboys of diversified northwest European lineage. The Table VII means at age 7 years are supported by Meredith and Culp (14). From an analysis of 1937-49 data on an Iowa sample of 125 American-born boys of northwest European lineage, these investigators report 44.8 as the mean at 7 years for calf girth in percentage of infraischia-soles distance.

3. The American-Dutch and American-North European comparisons for mean skelic index do not furnish clean-cut results. At age 7 years, the difference is not significant statistically; at age 15 years, the difference is significant at the 5 per cent level.

Regarding the trend of index means, results from various investigations show:

1. The body stem becomes more slender with age in early childhood and more stocky with age in later childhood and early adolescence. Meredith and Culp (14) found the mean stem index of Iowa boys of northwest European descent to decline from 88.7 at 4 years, through 87.4 at 6 years, to 86.4 at 8 years. A rising trend thereafter to age 15 years is indicated by means from the present study (see

Table VI) and the combined studies on Oregon boys of northwest European descent by Meredith (11) and Trim and Meredith (26).[7]

2. Throughout childhood and adolescence, the lower limbs become continuously less stocky with age. Means for the lower limb index from Meredith and Culp (14) decrease from 50.1 at age 4 years, through 46.1 at age 6 years, to 43.6 at age 8 years. Tables VI and VII, supported by findings on girls from Meredith and Meredith (19), show that this index continues to fall during later childhood and early adolescence.

3. The mean trend for thorax girth in percentage of abdomen girth shows an overall rise from early childhood into adolescence, and a subsequent decline. Schwartz, Britten and Thompson (24), in a study on white boys residing in New York City, found the trunk index to increase from 102.3 at 4 years, through 112.1 at 10 years, to 116.5 at 17 years, then decrease to 112.5 at 25 years. These means are reproduced to depict the general trend on age; they are not directly comparable with the trunk index means in Table VI, since different methods of measuring thorax girth were used. Findings on Michigan and Oregon boys show little change in mean trunk index between ages 7 years and 10 years (11) or 11 years (Table VI), followed by increase between these ages and 15 years (Table VII).

4. The infraischial component of stature increases in relation to the stem component throughout the period from infancy to early adolescence, then decreases slightly during late adolescence. Meredith and Knott (17) found the mean trend for the skelic index on Iowa boys of northwest European ancestry rose from 51.7 at birth, through 82.9 at 7 years, to 94.6 at 14 years, and descended to 90.8 at 18 years. The sequential means secured in the present study (see Table VI) harmonize with this trend.

Two of the findings for American-Dutch boys on covariation of body form indices at age 11 years are in broad agreement with findings for American-North European boys at other ages. Explicitly,

1. Obtained r's symbolizing correlation of the stem and lower limb indices are 0.28 at 5 years (14), 0.40 at 7 years (11), 0.53 at 7 years (14), 0.38 at 10 years (11), 0.69 at 11 years (present study) and 0.58 at 15 years (26). These coefficients allow the generalization of low to moderate positive association between the 2 slender-to-stocky continua.

[7] Meredith and Sherbina (20) found that in girls the shift from a falling curve to an ascending curve occurs between ages 7 years and 8 years.

2. Obtained *r*'s expressing relationship of the lower limb and trunk indices are —0.44 at age 11 years (present study) and —0.34 at age 15 years (26). Generalizing, there is low to moderate negative association in late childhood and early adolescence between the slender-to-stocky continuum for the lower limb and the regional predominance continuum for the trunk.

Summary

North American schoolboys of Dutch lineage have been studied with respect to 7 measures of body size and 4 measures of body form. The boys were drawn from the schools of Holland, Michigan, during the 1957-58 academic year.

The data for body size are measurements of stature, stem length, lower limb length, thorax girth, abdomen girth, calf girth, and body weight. Body form data are derived as thorax girth x 100/stem length, calf girth x 100/lower limb length, thorax girth x 100/abdomen girth, and lower limb length x 100/stem length.

Analyses have been made to obtain both indigenous and comparative findings. Selected results are:

1. Compared with Michigan boys of Dutch descent studied 25 years ago, present day Michigan boys of Dutch descent are heavier in mean body weight by approximately 5.0 kg. at age 11 years and 10.0 kg. at age 15 years.

2. Comparing contemporary American-Dutch and American-Japanese boys at 15 years of age, these 2 subgroups are similar in mean stem length, although the latter subgroup is the shorter in mean lower limb length by about 7.0 cm.

3. During the postnatal period from age 7 years to age 15 years, the body stem becomes more stocky and the lower limbs become more slender.

4. In childhood, calf girth varies more strongly with thorax girth and abdomen girth (*r*'s = ca. 0.8) than with lower limb length (*r* = ca. 0.4).

5. At childhood and adolescent ages, there is a modest direct association between lower limb and stem stockiness, and a modest inverse association between lower limb stockiness and predominance of thorax girth over abdomen girth.

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BOOK REVIEW

LIST OF FILMS ON HUMAN ANATOMY AND EMBRYOLOGY. Publ. by Netherlands Scientific Film Association. 2nd ed. 1957. $3.00 (Hfl. 10); £ 1 (= 1 English pound).

The films listed are divided into four groups—Embryology; Systematic Anatomy; Topographic Anatomy; and Miscellaneous. The first group deals mainly with human embryology, comprising films on human reproduction and development in general; human ovulation; development of the human egg; and a study of human spermatozoa. Seventeen films are devoted to the embryonic development of specific organs or organ systems, and there are several others dealing with developmental anomalies. There are also two films devoted to conjoined twins, and one on normal twinning.

The second group of films portrays systematic anatomy of (1) cardiovascular system and blood, (2) respiratory system, (3) alimentary tract and digestive system, (4) urogenital system, (5) locomotor system, osteology, articulation, musculature, and integumentary system, (6) nervous system and sense organs, and (7) lymphatic system and endocrine organs.

The third group lists films on the topographic anatomy of the thorax, abdomen, pelvis, upper and lower extremities, and head, face, and neck.

The fourth group "Miscellaneous," is concerned chiefly with cell studies and the processes of meiosis, mitosis in normal and malignant tissues, and a number of studies on growth *in vitro*.

An appendix of 34 pages lists names and addresses of persons or organizations where films can be secured.

Those ordering the list are requested to draw checks payable to the order of the Treasurer of the Netherlands Scientific Film Association at Catharijnesingel 59, ingang Sterrenbos, Utrecht.

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